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THE ARC SPECTRUM OF RHENIUM

By William F. Meggers

ABSTRACT

With pure potassium perrhenate on silver electrodes, the arc and spark spectra of rhenium have been photographed from 2,100 A in the ultra-violet to 8,800 A in the infra-red; more than 3,000 new spectral lines have been recorded in this range. Only the lines appearing in the arc spectra with wave lengths exceeding 2,500 A are presented at this time. About 25 per cent of the 2,000 or more lines herein described show hyperfine structure of 2 to 6 or more components. The centers of gravity of complex lines have been determined and are assumed to represent the effective wave lengths for purposes of analyzing the gross structure of the Re I spectrum. About 500 lines, including all those of intensity greater than 20 on a scale of 1 to 2,000, have been classified as combinations of 115 levels, belonging to quartet, sextet, and octet systems, but only a part of the levels have been completely identified. The raie ultime is recognized as the line at 3,460.47 A, $a^6S_{2\frac{1}{2}} - e^6P^{\circ}_{3\frac{1}{2}}$, the normal state of the neutral Re atom being represented by $(d^5s^2)\ a^6S_{2\frac{1}{2}}$. Series forming terms have been identified which indicate that the ionization potential is approximately 7.85 volts.

In 1869 Mendeléev predicted the existence and properties of two chemical elements which should be homologous to manganese; these he called "eka-manganese" and "dvi-manganese." Within the past two decades atomic number has been recognized as a fundamental property of the atom, and the two unknown elements have often been referred to as 43 and 75. After many years of fruitless search by an unknown number of investigators, the problem was attacked by Walter Noddack and Ida Tacke, who announced,[1] in 1925, the discovery of both 43 and 75, and proposed the names "masurium" and "rhenium" for the newly concentrated and identified elements. The discoverers outlined a procedure based on the expected chemical properties whereby the concentrations of these rare elements in certain minerals could be enriched 1,000 fold or more until their presence could be established by the appearance of accurately predictable lines in the Röntgen spectra. Thus the first announcement related to material containing about 0.5 per cent masurium and 5 per cent rhenium, and the proof of their identity was contained in the following table of Röntgen spectra:[2]

	Masurium 43			Rhenium 75				
Line symbol	$K_{\alpha 1}$	$K_{\alpha 2}$	$K\beta_1$	$L_{\alpha 1}$	$L_{\alpha 2}$	$L\beta_1$	$L\beta_2$	$L\beta_3$
Measured wave length ... A	0.672	0.675	0.601	1.4299	1.4407	1.235	1.2048	1.216
Calculated wave length ... do	.6734	.6779	.6000	1,4306	1.4406	1.2355	1.2041	1.2169

Apparently little progress has been made in concentrating and purifying masurium, but the rapidity with which the supply of

[1] W. Noddack and I. Tacke, Naturwissenschaften, **13**, p. 567; 1925.
[2] V. Berg and I. Tacke, Naturwissenschaften, **13**, p. 571; 1925.

rhenium, and information concerning its physical and chemical properties, has increased is truly remarkable. In 1927 only 2 mg of rhenium had been concentrated;[3] in 1928 about 120 mg were prepared[4] (at a cost of 30,000 marks), the production of an entire gram of rhenium was described[5] in 1929, while the possibility of an annual production of 120 kg was announced[6] in 1930. Along with the increasing availability of rhenium has come an extensive accumulation of facts as to its chemical and physical properties.[7] In particular, the Röntgen spectra of rhenium have been thoroughly investigated;[8] the wave lengths of 25 L-series lines, 4 M-series lines and 3 L-absorption limits were published by Beuthe in 1928. It is rather surprising, however, that no details concerning the optical emission spectra of rhenium were published until the present writer[9] called attention to some on December 23, 1930. To be sure the discoverers announced,[10] in 1928, that the arc and spark spectra of rhenium were qualitatively known and that several hundred lines were known certainly to belong to rhenium, but no details were given except that the ultimate lines of the optical spectrum, especially the triplet at 3,640 A [11] serve to detect rhenium in concentrations down to 10^{-7} and greatly facilitate the examination of rhenium-containing materials.

The optical spectra of rhenium may be expected to be of considerable interest to both practical and theoretical spectroscopists and it was with this point of view that the writer undertook a description and analysis of the spectra when pure material became available. The material used in this investigation was a portion of 1 g of potassium perrhenate ($KReO_4$) kindly presented to this bureau in November, 1930, by Dr. A. v. Grosse, of the Institute of Technology of Berlin. A few crystals of this salt were fused on silver rods in the electric arc, and the spectrum was photographed with a Rowland concave grating mounted stigmatically. The grating has a radius of curvature of 21½ feet and is ruled with 20,000 lines per inch. The entire spectrum from 2,340 to 8,000 A was photographed in the first order spectrum with a scale of 3.7 A per millimeter and a portion (from 2,600 to 4,000 A) was also observed in the second order spectrum with a scale of 1.8 A per millimeter. The observations in the red and infra-red were supplemented and extended to 8,800 A with exposures to a similar spectrograph containing an Anderson ruled

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[3] I. Noddack and W. Noddack, Zeit. Angew. Chem., **125**, p. 264; 1927.

[4] I. Noddack and W. Noddack, Zeit. Electrochem., **34**, p. 627; 1928.

[5] I. Noddack and W. Noddack, Zeit. Anorg. Allgem. Chem., **183**, p. 353; 1929.

[6] W. Feit, Zeit. Angew. Chem., **43**, p. 459; 1930.

[7] I. and W. Noddack, Preparation and Some Chemical Properties of Re, Zeit. Angew. Chem., **125**, p. 264; 1927.

W. Noddack, The Chemistry of Rhenium, Zeit. Elektrochemie, **34**, p. 627; 1928.

I. Noddack, Some Physical Constants of Re, Zeit. Elektrochemie, **34**, p. 629; 1928.

I. and W. Noddack, Oxygen Compounds of 75, Naturwissenschaften, **17**, p. 93; 1929.

I. and W. Noddack, New researches on the properties of Rhenium, Forshungen und Fortschritte, **1**, p. 3; 1929.

Agte, Alterthun, Becker, Hyne & Moers, The Physical Properties of Re, Naturwissenschaften, **19**, p. 108; 1931.

[8] O. Berg, The Röntgen Spectrum of 75, Physik. Zeit., **28**, p. 864; 1927.

H. Beuthe, The L-series of Re, Z. Physik., **46**, p. 873; 1928.

I. Wennerlöf, Precision measurements in the L-series of 75, Z. Physik., **47**, p. 422; 1928.

H. Beuthe, Further Röntgen spectroscopy measurements in the L and M series of Re, Z. Physik., **50**, p. 762; 1928.

E. Lindberg, Measurements of the M-series from U (92) to Gd (66), Z. Physik., **50**, p. 82; 1928; **56**, p. 402; 1929.

[9] W. F. Meggers, The Optical Spectra of Rhenium, Phys. Rev., **37**, p. 219, 1931. B. S. Tech. News Bulletin, February, p. 11; 1931.

An announcement has recently appeared stating that a list of rhenium wave lengths is being published by Schober and Birke (Naturwissenschaften **19**, p. 211; 1931). Judging from their abbreviated list the values will be on the old Rowland scale.

[10] I. Noddack, Zeit. Elektrochem, **34**, p. 629; 1928.

[11] Probably a typographical error for 3,460.

grating with 7,500 lines per inch giving a scale of 10.4 A per millimeter. A Hilger E_1 quartz spectrograph was employed in photographing the Re spectra from 2,500 to 2,100 A, but the spectra are too complex to be satisfactorily described with this instrument. After each arc spectrum exposure the same electrodes were used in a high-voltage spark to record alongside the arc spectrum an exposure of the spark spectrum, thus permitting a sharp division of lines belonging to neutral atoms from those characteristic of ionized atoms. In the list presented here (Table 1) only the lines appearing in the exposure to the 220-volt direct-current arc are given, and some of these are marked E because they appear enhanced in the spark spectrum. Furthermore, only the lines of wave length greater than 2,500 A are being published at the present time because it is planned to reobserve the shorter ones with larger dispersion and higher resolving power so as to obtain satisfactory precision in the wave-length measurements and get some qualitative information as to hyperfine structure comparable with that now available in the visible spectrum. It may be remarked that a very striking feature of the rhenium emission spectra is seen in the complexity of many of its lines. This hyperfine structure is relatively coarse, as might be expected from a heavy odd-numbered atom, and in some cases the components of a line actually cover a wave-number interval of two units. From two to six components have been recognized for different lines, but no systematic effort to resolve hyperfine structures has been attempted thus far. Analysis of the hyperfine structure will be taken up in the immediate future, but for the present we are interested mainly in the gross structure of the spectra. For the purpose in hand the effective wave length of a complex line is regarded as the center of gravity of its unresolved components, and an effort has been made to determine these mean wave lengths with some precision. If the spectrographic resolving power is not too large the image of a complex rhenium line will appear as a narrow rectangle with approximately uniform intensity distribution, and the effective wave length of such a line is taken as the value corresponding to the bisected rectangle in narrow ones or the mean of the opposite edges of wider ones. The spread of the components is indicated qualitatively by letters following the intensity estimate, c signifying complex, cw complex and wider, averaging about one wave number; cW complex and still wider, ranging from one to two wave numbers. In come cases where incipient resolution occurred the unresolved side of the line is indicated by v for violet and l for longer waves. A few lines appearing to be double are marked d.

TABLE 1.—*The arc spectrum of rhenium* (Re_I)

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
2, 500. 59	2	39, 978. 51		2, 515. 46	1	39, 742. 20	
2, 501. 72	5	39, 960. 46		2, 516. 11	15	39, 731. 93	
2, 502, 37	3 E	39, 950. 08		2, 520. 01	8	39, 670. 45	1- 51
2, 504. 60	2	39, 914. 51		2, 521. 56	5 c	39, 646. 07	
2, 505. 41	1	39, 901. 61		2, 525. 56	1	39, 583. 28	
2, 505. 96	4	39, 892. 85		2, 526. 83	1	39, 563. 39	
2, 507. 42	3	39, 869. 62		2, 529. 50	3	39, 521. 63	
2, 508. 98	40	39, 844. 84	1- 52	2, 532. 92	1 d?	39, 468. 27	
2, 512. 55	1	39, 788. 22		2, 533. 32	3	39, 462. 04	
2, 514. 51	3	39, 757. 21		2, 534. 10	1 E	39, 449. 89	

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
2,534.80	5 c	39,439.00		2,611.61	10	38,279.14	
2,539.33	1	39,368.64		2,612.76	1	38,262.29	
2,540.51	4	39,350.36	2-109	2,612.91	1	38,260.09	
2,541.09	1 h	39,341.38		2,613.23	1	38,255.41	
2,543.68	2	39,301.33		2,613.76	3	38,247.65	
2,543.83	1	39,299.01		2,614.56	5	38,235.95	
2,544.22	2	29,292.98		2,615.70	1 E	38,219.29	
2,544.75	10	39,284.80		2,616.72	1 E	38,204.39	
2,544.89	2	39,282.64		2,617.14	2	38,198.26	
2,545.49	5	39,273.38		2,617.47	2	38,193.44	
2,548.13	2	39,232.70		2,620.04	4	38,155.98	
2,548.89	3	39,221.00		2,620.36	3	38,151.32	
2,550.09	1 E	39,202.54		2,621.18	2	38,139.39	
2,552.02	4	39,172.90		2,621.99	2	38,127.60	
2,552.70	1	39,162.46		2,622.77	5	38,116.26	
2,553.57	1 E	39,149.12		2,623.30	2	38,108.57	
2,554.18	2	39,139.77		2,625.05	1	38,083.16	
2,554.63	2 E	39,132.88		2,625.82	1	38,072.00	
2,554.94	1	39,128.13		2,630.17	1	38,009.03	
2,555.66	1	39,117.11		2,630.77	2	38,000.36	
2,556.50	20	39,104.26		2,631.59	3	37,988.53	
2,558.05	2	39,080.56		2,633.02	1	37,967.90	
2,559.07	5	39,064.99	1- 47	2,633.63	3	37,959.10	
2,559.74	2	39,054.77		2,635.84	2 E	37,927.28	
2,559.88	1	39,052.63		2,636.64	20	37,915.77	1- 41
2,561.46	2	39,028.54		2,637.00	2 E	37,910.60	
2,563.01	2	39,004.94		2,641.02	1 E	37,852.90	
2,564.19	4	38,986.99		2,641.18	1	37,850.60	
2,565.84	1	38,961.92		2,642.76	8	37,827.98	
2,568.65	3 E	38,919.30		2,644.77	1	37,799.23	
2,571.26	3	38,879.80		2,645.81	1	37,784.37	
2,571.82	2 E	38,871.33		2,646.40	1	37,775.95	
2,573.78	3	38,841.73		2,647.14	6	37,765.39	1- 40
2,574.22	1	38,835.10		2,648.49	1 E	37,746.14	
2,576.33	2	38,803.29		2,649.06	7	37,738.02	
2,578.14	1	38,776.05		2,649.58	2	37,730.61	
2,579.02	3	38,762.82		2,651.90	20	37,697.60	1- 39
2,580.31	1	38,743.44		2,652.92	3	37,683.11	
2,581.43	3	38,726.64		2,653.74	1	37,671.47	
2,582.79	2	38,706.24		2,654.12	7	37,666.08	
2,584.77	2	38,676.60		2,655.18	2	37,651.04	
2,586.80	10	38,646.25		2,655.84	2	37,641.68	
2,587.02	1	38,642.96		2,657.45	1	37,618.88	
2,587.18	1	38,640.57		2,658.69	1	37,601.34	
2,591.14	2	38,581.52		2,659.02	2	37,596.67	
2,591.47	1	38,576.61		2,659.79	2	37,585.79	
2,591.60	3	38,574.68		2,660.56	1 h	37,574.91	
2,592.85	2 c?	38,556.08		2,661.02	1	37,568.41	
2,594.86	4	38,526.22	2-103	2,663.63	8	37,531.61	
2,595.24	7	38,520.58	1- 44	2,664.21	2	37,523.43	
2,596.42	2	38,503.07		2,664.80	2	37,515.13	
2,596.79	3	38,497.58		2,667.13	2	37,482.35	
2,596.96	2	38,495.06		2,667.79	1	37,473.08	
2,597.98	1	38,479.95		2,670.23	3	37,438.84	2-100
2,598.60	1	38,470.77		2,670.80	3	37,430.85	
2,599.86	8	38,452.13		2,671.84	4	37,416.28	
2,600.87	1	38,437.19		2,672.77	2	37,403.27	
2,601.89	2	38,422.13		2,674.33	40	37,381.45	1- 38
2,602.55	1	38,412.39		2,677.04	3	37,343.61	
2,602.93	2	38,406.78		2,677.77	2	37,333.43	
2,603.47	2	38,398.81		2,679.09	2	37,315.04	
2,603.88	6 c?	38,392.77		2,679.92	4	37,303.48	
2,607.32	1	38,342.12		2,681.02	1	37,288.18	
2,608.51	4 E	38,324.63		2,683.56	4	37,252.88	
2,609.41	1	38,311.41		2,685.30	2	37,228.75	

TABLE 1.—*The arc spectrum of rhenium* (*Re I*)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
2, 688. 53	8	37, 184. 02		2, 768. 86	4	36, 105. 30	3- 94
2, 689. 34	2	37, 172. 82		2, 769. 33	3 c	36, 099. 18	
2, 690. 26	4	37, 160. 11		2, 770. 41	10	36, 085. 11	2- 93
2, 690. 79	3	37, 152. 80		2, 771. 62	1	36, 069. 35	
2, 693. 76	1 h	37, 111. 84		2, 772. 42	1	36, 058. 95	
2, 694. 40	3	37, 103. 02		2, 773. 12	4	36, 049. 84	
2, 695. 56	4	37, 087. 05		2, 774. 39	1	36, 033. 34	
2, 697. 27	4	37, 063. 54	1- 37	2, 775. 64	2	36, 017. 12	
2, 698. 79	1	37, 042. 67		2, 775. 94	1	36, 013. 22	
2, 699. 58	1	37, 031. 83		2, 776. 95	1	36, 000. 12	
2, 702. 68	2	36, 989. 36		2, 777. 22	1	35, 996. 63	
2, 703. 28	1	36, 981. 15		2, 777. 73	2	35, 990. 02	
2, 704. 39	4	36, 965. 97		2, 778. 09	2	35, 985. 35	
2, 706. 06	1	36, 943. 16		2, 778. 50	2	35, 980. 04	
2, 706. 50	1	36, 937. 15		2, 779. 31	1	35, 969. 56	
2, 707. 40	1	36, 924. 87		2, 780. 80	1 h	35, 950. 29	
2, 707. 84	1	36, 918. 88		2, 781. 44	4	35, 942. 02	
2, 710. 23	1	36, 886. 32		2, 783. 16	1	35, 919. 81	
2, 712. 49	2	36, 855. 59		2, 783. 57	12 c	35, 914. 51	3- 93
2, 713. 04	3	36, 848. 12		2, 785. 20	4	35, 893. 50	6-103
2, 713. 17	2	36, 846. 35		2, 785. 43	2	35, 890. 53	
2, 713. 68	1	36, 839. 43		2, 785. 72	2	35, 886. 80	
2, 715. 47	40	36, 815. 14	3- 99	2, 786. 14	2	35, 881. 39	
2, 715. 78	4	36, 810. 94		2, 786. 55	4	35, 876. 11	9-109
2, 716. 77	3	36, 797. 53		2, 787. 41	1	35, 865. 04	
2, 719. 55	2	36, 759. 92		2, 789. 26	3 d	35, 841. 26	
2, 720. 66	1	36, 744. 92		2, 790. 94	4	35, 819. 68	
2, 722. 21	4	36, 724. 00		2, 791. 29	8	35, 815. 19	
2, 722. 72	6	36, 717. 12	6-109	2, 791. 60	1	35, 811. 21	
2, 723. 36	1	36, 708. 49		2, 793. 68	1	35, 784. 55	
2, 723. 86	1	36, 701. 75		2, 794. 16	1	35, 778. 40	
2, 727. 55	3	36, 652. 11		2, 796. 07	1	35, 753. 97	
2, 728. 63	2	36, 637. 60		2, 796. 60	1	35, 747. 19	
2, 729. 65	2	36, 623. 91		2, 797. 45	1	35, 736. 33	
2, 730. 84	2	36, 607. 95		2, 798. 11	3	35, 727. 90	
2, 731. 56	3 c E	36, 598. 30		2, 800. 70	7 c	35, 694. 86	
2, 732. 21	8	36, 589. 60		2, 802. 25	4	35, 675. 12	
2, 733. 04	6 E	36, 578. 48		2, 802. 83	1	35, 667. 74	
2, 734. 32	2	36, 561. 36		2, 803. 26	4 E	35, 662. 27	
2, 734. 90	2	36, 553. 61		2, 805. 98	1	35, 627. 70	
2, 738. 33	3	36, 507. 83		2, 807. 87	3 c	35, 603. 72	
2, 738. 73	1 d	36, 502. 49		2, 812. 07	2	35, 550. 55	
2, 739. 97	2	36, 485. 98		2, 812. 37	3	35, 546. 75	
2, 741. 98	1	36, 459. 23		2, 813. 12	2	35, 537. 28	
2, 742. 78	1	36, 448. 60		2, 813. 96	5	35, 526. 67	
2, 742. 86	2	36, 447. 53		2, 814. 67	10	35, 517. 79	
2, 743. 88	3	36, 433. 98		2, 815. 64	1	35, 505. 47	
2, 744. 21	1	36, 429. 60	3- 98	2, 816. 33	4	35, 496. 77	
2, 745. 87	2	36, 407. 58		2, 816. 96	4	35, 488. 84	8-103
2, 747. 43	4	36, 386. 91	2- 97	2, 819. 95	30 cw	35, 451. 21	3- 92
2, 752. 88	3	36, 314. 88		2, 822. 12	3	35, 423. 95	
2, 753. 06	4	36, 312. 50	8-109	2, 822. 42	1	35, 420. 19	2- 91
2, 753. 66	1 h E	36, 304. 59		2, 823. 21	3	35, 410. 27	
2, 755. 22	2	36, 284. 04	5-103	2, 823. 88	1 E	35, 401. 88	
2, 757. 50	2	36, 254. 04		2, 824. 25	3	35, 397. 24	
2, 758. 02	8	36, 247. 20		2, 825. 46	2 E	35, 382. 08	
2, 758. 72	2	36, 238. 01		2, 826. 77	1 h	35. 365. 68	
2, 761. 93	3	36, 195. 89		2, 827. 52	3	35, 356. 30	
2, 763 31	2	36, 177. 82	3- 96	2, 827. 83	1	35, 352. 43	
2, 763. 79	4	36, 171. 53		2, 829. 88	1	35, 326. 82	
2, 766. 06	1	36, 141. 85		2, 830. 10	1	35, 324. 07	
2, 766. 40	2 c	36, 137. 41		2, 830. 82	1	35, 315. 09	
2, 766. 54	1	36, 135. 58		2, 834. 08	10 c	35. 274. 47	
2, 767. 75	8	36, 119. 79		2, 834. 62	2	35, 267. 75	1- 34
2, 768. 28	1	36, 112. 87		2, 836. 69	1	35, 242. 01	

TABLE 1.—*The arc spectrum of rhenium (Re_I)*—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
2,837.01	1	35,238.04		2,913.81	1	35,309.31	
2,837.54	6	35,231.46		2,915.27	1	35,292.12	
2,838.10	1	35,224.51		2,916.29	1 h	35,280.13	
2,839.18	1	35,211.11		2,916.80	1 d	35,274.14	
2,840.35	7	35,196.60	5–100	2,918.87	2	35,249.83	
2,842.99	7	35,163.92	10–109	2,919.41	84	34,243.50	
2,844.16	3	35,149.46		2,921.71	1	34,216.54	
2,846.48	1	35,120.81		2,924.60	6 cw	34,182.73	3– 84
2,846.97	3	35,114.76		2,925.19	3	34,175.84	
2,847.73	1	35,105.39		2,926.94	2	34,155.40	
2,848.23	2 d	35,099.23		2,927.42	20 cw	34,149.81	
2,850.28	1	35,073.99		2,927.70	1	34,146.54	
2,850.97	10	35,065.50	2– 90	2,928.58	1	34,136.28	
2,852.38	1	35,048.17		2,929.53	5	34,125.21	
2,852.85	3	35,042.40		2,930.60	7	34,112.75	
2,855.52	2	35,009.63		2,931.67	1	34,100.30	
2,857.44	2	34,986.11		2,932.28	2 d	34,093.21	
2,860.08	2	34,953.82		2,933.44	1	34,079.73	
2,860.26	2	34,951.62		2,934.01	1	34,073.11	5– 95
2,862.18	1	34,928.17		2,936.50	3	34,044.22	
2,862.88	2	34,919.63		2,937.83	1	34,028.80	
2,864.57	2	34,899.03		2,938.80	1	34,017.57	
2,864.81	1	34,896.11		2,940.99	1 E	33,992.24	
2,867.20	8	34,867.02		2,941.56	2	33,985.66	
2,868.14	1	34,855.59		2,943.14	10	33,967.41	6– 98
2,871.81	6	34,811.05	6–101	2,943.39	2+E?	33,964.53	9–100
2,872.29	2	34,805.24		2,944.34	2	33,953.57	
2,872.67	1	34,800.63		2,945.70	2	33,937.89	
2,875.28	6	34,769.04	2– 87	2,945.88	1	33,935.82	
2,876.03	1	34,759.98		2,946.57	2	33,927.87	
2,876.87	2	34,749.83		2,949.10	3	33,898.77	
2,879.28	2	34,720.74		2,949.26	1	33,896.93	
2,881.88	1 E	34,689.42		2,949.89	2	33,889.69	4– 86
2,882.23	1	34,685.21		2,950.84	4	33,878.78	2– 83
2,883.45	6	34,670.53		2,954.34	3	33,838.65	
2,884.04	2	34,663.44		2,954.62	1 d	33,835.44	
2,884.64	3	34,656.23		2,957.90	1 c E	33,797.92	
2,885.17	1 d	34,649.87		2,958.92	2	33,786.27	
2,885.93	1	34.640.74		2,959.32	1	33,781.70	
2,886.95	2	34,628.50		2,959.77	1	33,776.57	
2,887.35	2	34,623.71		2,960.29	1	33,770.64	
2,887.67	60	34,619.87	3– 88	2,961.76	3 c	33,753.88	6– 97
2,888.04	2 E	34,615.43		2,962.27	8	33,748.06	
2,889.45	3	34,598.54	3– 87	2,962.86	2	33,741.34	
2,891.48	3	34,574.25		2,965.12	20 c	33,715.63	6– 96
2,891.88	6	34,569.47		2,965.75	40 cw	33,708.47	3– 83
2,892.63	4	34,560.51		2,967.25	3	33,691.43	
2,894.32	3	34,540.33		2,968.05	5	33,682.35	6– 95
2,895.67	2	34,524.23		2,968.97	2	33,671.91	
2,896.00	20 cw	34.520.30	1– 31	2,975.04	2	33,603.21	15–109
2,896.44	1	34,515.05		2,975.25	3	33,600.84	
2,897.59	2	34,501.35		2,976.29	10 c	33,589.10	{1– 28 {3– 82
2,898.79	2	34,487.07		2,977.30	2	33,577.71	
2,902.50	20 cW	34,442.99	17–115	2,978.15	5	33,568.12	
2,904.53	1 E	34,418.92		2,980.29	1	33,544.02	
2,905.42	2	35,408.38		2,980.84	5	33,537.83	
2,905.58	6	35,406.49	8–101	2,980.99	2	33,536.15	
2,906.01	5	35,401.39	8–100	2,982.19	5 c	33,522.65	
2,907.10	2	35,388.50		2,984.52	1	33,496.48	
2,908.34	3	35,373.83		2,984.75	2	33,493.90	
2,909.81	15	35,356.47		2,986.04	2	33,479.43	
2,910.08	2	35,353.28	2– 84	2,988.48	6	33,452.10	6– 93
2,911.23	2	35,339.71	10–103	2,991.86	1	33,414.31	
2,912.50	1	35,323.68		2,992.36	50	33,408.72	1– 26
2,913.15	2	35,317.08		2,992.80	2 c	33,403.81	

TABLE 1.—*The arc spectrum of rhenium* (Re_{I})—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
2, 993. 18	2	33, 399. 57		3, 065. 58	2	32, 610. 81	9- 93
2, 995. 39	3	33, 374. 93		3, 067. 39	50	32, 591. 56	1- 25
2, 997. 70	1	33, 349. 21	8- 97	3, 068. 76	2	32, 577. 01	
2, 998. 55	1	33, 339. 76		3, 069. 94	10	32, 564. 49	
2, 999. 58	80	33, 328. 31	3- 81	3, 071. 16	6	32, 551. 56	
3, 000. 59	1	33, 317. 09		3, 071. 76	3 hl	32, 545. 20	
3, 001. 13	8	33, 311. 10		3, 072. 45	1	32, 537. 89	
3, 004. 13	7	33, 277. 84	8- 95	3, 072. 96	6	32, 532. 49	
2, 004. 34	2	33, 275. 51		3, 075. 02	2 h	32, 510. 70	
3, 005. 23	1	33, 265. 66		3, 076. 14	3	32, 498. 86	
3, 005. 96	3	33, 257. 58	10-101	3, 076. 28	1	32, 497. 38	
2, 006. 43	7	33, 252. 38	10-100	3, 078. 87	4	32, 470. 05	3- 76
3, 007. 04	2	33, 245. 63		3, 080. 92	2	32, 448. 44	
3, 007. 19	2	33, 243. 98		3, 081. 63	1	32, 440. 97	
3, 010. 64	1	33, 205. 88		3, 082. 43	20 cw v	32, 432. 55	6- 90
3, 011. 47	1	33, 196. 73		3, 082. 76	1	32, 429. 08	
3, 011. 94	4 cw	33, 191. 55		3, 084. 21	4 c	32, 413. 83	10- 98
3, 013. 15	6	33, 178. 22	5- 91	3, 084. 79	2	32, 407. 74	
3, 014. 95	1	33, 158. 41		3, 085. 36	1	32, 401. 75	
3, 016. 02	20 cw v	33, 146. 65	3- 79	3, 085. 54	1	32, 399. 86	
3, 016. 48	10	33, 141. 60		3, 087. 16	3	32, 382. 86	8- 91
3, 016. 96	2	33, 136. 32		3, 088. 76	10	32, 366. 08	
3, 017. 27	1	33, 132. 92		3, 089. 93	2	32, 353. 83	
3, 017. 59	1	33, 129. 40		3, 092. 33	1	32, 328. 72	
3, 021. 88	6	33, 082. 38		3, 093. 64	6 c	32, 315. 03	5- 86
3, 022. 99	3	33, 070. 23		3, 095. 06	4	32, 300. 20	
3, 023. 59	1	33, 063. 67		3, 095. 80	6 cw	32, 292. 48	6- 89
3, 025. 05	2	33, 047. 71	8- 93	3, 096. 41	3	32, 286. 12	5- 85
3, 026. 26	2	33, 034. 50		3, 097. 93	1	32, 270. 28	
3, 030. 44	15 c	32, 988. 93	6- 92	3, 098. 27	1	32, 266. 74	
3, 031. 26	2	32, 980. 01		3, 099. 70	1 c	32, 251. 86	
3, 032. 79	3	32, 963. 37		3, 100. 66	20	32, 241. 87	12-99?
3, 034. 53	5	32, 944. 47	18-115	3, 101. 00	1	32, 238. 34	
3, 035. 61	2	32, 932. 75		3, 101. 71	1	32, 230. 96	
3, 036. 55	3	32, 922. 56		3, 103. 08	2 E	32, 216. 73	
3, 037. 44	1	32, 912. 91	9- 97	3, 103. 26	2 c E	32, 214. 86	
3, 037. 95	4	32, 907. 39		3, 104. 65	4	32, 200. 44	10- 97
3, 040. 04	5 cw	32, 884. 76		3, 107. 86	1 d	32, 167. 18	
3, 041. 00	3	32, 874. 38	9- 96	3, 108. 80	40	32, 157. 45	6- 88
3, 041. 24	1	32, 871. 79		3, 109. 75	2	32, 147. 63	9- 92
3, 041. 76	1	32, 866. 17		3, 110. 86	12	32, 136. 16	6- 87
3, 041. 99	2	32, 863. 68		3, 111. 57	3	32, 128. 83	10- 95
3, 042. 29	2	32, 860. 44		3, 113. 21	2	32, 111. 90	
3, 044. 08	3	32, 841. 12	9- 95	3, 113. 97	1	32, 104. 07	
3, 045. 28	1	32, 828. 18		3, 114. 62	1	32, 097. 37	
3, 046. 00	1	32, 820. 42		3, 118. 20	20 cW v	32, 060. 52	
3, 047. 26	6 c?	32, 806. 85		3, 119. 22	2	32, 050. 03	
3, 048. 58	1	32, 792. 65		3, 119. 85	1	32, 043. 56	
3, 049. 79	2	32, 779. 64	15-103	3, 120. 24	1	32, 039. 56	
3, 051. 60	1	32, 760. 20		3, 121. 37	12 c	32, 027. 96	8- 90
3, 052. 24	1	32, 753. 33		3, 121. 73	1	32, 024. 26	
3, 052. 84	2 c?	32, 746. 89		3, 122. 22	1	32, 019. 24	
3, 053. 62	3	32, 738. 52		3, 123. 17	3	32, 009. 50	
3, 054. 90	4	32, 724. 81	2- 77	3, 123. 40	1	32, 007. 14	
3, 056. 00	2 c	32, 713. 03		3, 125. 35	1 h	31, 987. 17	
3, 056. 45	1	32, 708. 21		3, 125. 52	3	31, 985. 43	2- 72
3, 057. 66	3	32, 695. 27	12-100	3, 126. 03	1	31, 980. 22	
3, 057. 86	2	32, 693. 13		3, 128. 94	15 cw	31, 950. 47	13- 99
3, 058. 78	7	32, 683. 30	5- 89	3, 131. 27	1 h	31, 926. 70	
3, 060. 32	3	32, 666. 85		3, 132. 03	2 h	31, 918. 95	7- 87
3, 061. 21	1	32, 657. 36		3, 134. 02	6	31, 898. 69	10- 93
3, 061. 61	3	32, 653. 09		3, 134. 34	1	31, 895. 43	6- 85
3, 062. 50	1	32, 643. 60		3, 135. 07	3 c	31, 888. 00	8- 89
3, 064. 61	2	32, 621. 13		3, 138. 02	1	31, 858. 03	
3, 065. 28	2	32, 614. 00		3, 139. 80	3 c	31, 839. 97	

TABLE 1.—*The arc spectrum of rhenium* (*Re* I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination
3, 139.94	2	31, 838.55	
3, 141.37	7	31, 824.06	2– 69
3, 141.71	1	31, 820.61	
3, 142.63	5 c	31, 811.30	
3, 145.58	1	31, 781.46	
3, 146.53	2	31, 771.87	
3, 147.70	1	31, 760.06	
3, 147.89	1	31, 758.14	2– 68
3, 148.20	2	31, 755.02	
3, 150.05	1	31, 736.37	
3, 150.53	1	31, 731.53	8– 87
3, 151.16	2	31, 725.19	
3, 151.63	15 cw	31, 720.46	6– 84
3, 153.77	10	31, 698.94	3– 71
3, 156.84	1	31, 668.11	
3, 157.70	1	31, 659.48	
3, 158.31	25 cW v	31, 653.37	3– 69
3, 159.30	2	31, 643.45	12– 97
3, 159.61	1 h	31, 640.35	
3, 160.19	2 h	31, 634.54	
3, 162.48	2 d?	31, 611.63	
3, 163.23	1	31, 604.14	
3, 164.13	1	31, 595.15	
3, 164.51	6	31, 591.36	9– 90
3, 164.85	2	31, 587.96	
3, 165.79	2	31, 578.58	
3, 166.47	2	31, 571.80	12– 95
3, 166.91	2	31, 567.41	
3, 167.15	3	31, 565.02	13– 98
3, 167.59	1	31, 560.64	
3, 168.36	30 cw	31, 552.97	11– 94
3, 170.98	2 c	31, 526.90	
3, 173.09	3	31, 505.94	
3, 174.61	6	31, 490.85	8– 85
3, 174.77	4 cw	31, 489.27	
3, 176.06	1	31, 476.48	
3, 177.71	15	31, 460.13	
3, 178.49	2	31, 452.41	
3, 178.60	5	31, 451.32	9– 89
3, 180.88	1	31, 428.78	
3, 182.70	3	31, 410.81	.
3, 182.87	25 c	31, 409.14	17–106
3, 184.75	50 c	31, 390.59	17–105
3, 185.56	40 c	31, 382.61	17–104
3, 186.28	3	31, 375.52	
3, 187.78	2	31, 360.76	
3, 190.17	4	31, 337.26	
3, 190.78	6	31, 331.27	14– 99
3, 192.36	6 c	31, 315.76	8– 84
3, 192.68	1	31, 312.63	
3, 193.19	3	31, 307.62	
3, 194.49	7 cw	31, 294.88	9– 87
3, 195.66	1	31, 283.43	
3, 197.24	1	31, 267.97	
3, 197.52	1	31, 265.23	
3, 198.57	6	31, 254.97	
3, 199.50	2	31, 245.88	6– 83
3, 200.03	5 cw	31, 240.71	13– 94
3, 200.72	3	31, 233.97	10– 91
3, 202.22	2	31, 219.34	
3, 204.24	60 cW l	31, 199.66	
3, 204.68	1	31, 195.38	
3, 205.42	3 c	31, 188.18	
3, 206.47	2	31, 177.97	
3, 207.78	2 c	31, 165.23	
3, 208.23	2	31, 160.86	
3, 211.75	4 c	31, 126.71	6– 82
3, 212.38	1	31, 120.61	
3, 212.94	3 cw	31, 115.18	
3, 213.48	2	31, 109.95	
3, 213.90	1	31, 105.89	
3, 214.11	2	31, 103.86	
3, 214.82	1	31, 096.99	
3, 219.74	1	31, 049.47	
3, 219.92	2 E	31, 047.74	
3, 220.45	1	31, 042.63	
3, 221.17	1	31, 035.69	
3, 221.84	1 E	31, 029.23	
3, 224.23	1	31, 006.23	
3, 227.46	4	30, 975.20	
3, 228.36	1 c	30, 966.57	
3, 228.74	3	30, 962.93	
3, 235.95	10	30, 893.94	
3, 237.00	1 h	30, 883.92	
3, 237.52	4	30, 878.96	{ 9– 84 10– 90
3, 238.36	1	30, 870.95	
3, 239.17	2	30, 863.23	
3, 241.47	3	30, 841.33	8– 83
3, 246.32	2 E	30, 795.26	
3, 248.55	3	30, 774.12	
3, 252.26	4	30, 739.01	10– 89
3, 253.18	2 c?	30, 730.32	
3, 253.95	3 cw	30, 723.05	
3, 255.80	1	30, 705.59	
3, 256.29	2	30, 700.97	
3, 258.07	1	30, 684.20	6– 79
3, 258.85	15	30, 676.86	12– 91
3, 259.55	20	30, 670.27	
3, 261.56	4 c?	30, 651.37	
3, 262.77	3	30, 640.00	15– 97
3, 266.85	3 c	30, 601.73	15– 96
3, 268.09	3 c	30, 590.12	
3, 268.49	5	30, 586.38	13– 92
3, 268.90	4 c	30, 582.54	10– 87
3, 269.04	3 c	30, 581.24	
3, 270.04	1	30, 571.88	
3, 271.09	1	30, 562.07	
3, 277.73	3 c?	30, 500.16	
3, 285.67	2	30, 426.46	
3, 287.12	2	30, 413.04	
3, 290.10	1	30, 385.49	3– 65
3. 294.82	4	30, 341.96	10– 85
3, 296.70	6 c	30, 324.66	17–102
3, 296.98	6 c v	30, 322.08	12– 90
3, 300.97	2	30, 285.43	9– 82
3, 301.59	5	30, 279.75	8– 79
3, 302.22	4	30, 273.97	
3, 303.21	5 cWE	30, 264.90	
3, 303.75	7	30, 259.95	2– 64
3, 304.85	1	30, 249.88	
3, 306.50	1	30, 234.79	
3, 307.00	3 c	30, 230.22	
3, 308.25	3	30, 218.79	
3, 308.46	3 cWE	30, 216.88	
3, 308.87	2	30, 213.13	
3, 309.31	2	30, 209.12	
3, 312.30	3	30, 181.84	12– 89
3, 313.95	6	30, 166.82	10– 84
3, 316.07	1	30, 147.52	
3, 317.01	1	30, 138.99	

TABLE 1.—*The arc spectrum of rhenium (Re_I)*—Continued

Wave length	Intensity and character	Vacuum wave number	Combination
3,317.75	1 E	30,132.27	
3,318.67	4	30,123.91	
3,320.66	1	30,105.86	
3,321.46	2	30,098.61	
3,322.21	2	30,091.82	6– 77
3,322.49	40 cw	30,089.28	3– 64
3,324.93	3	30,067.20	11– 88
3,326.88	1 c?	30,049.57	
3,327.20	2	30,046.69	
3,327.71	2	30,042.08	
3,328.17	1	30,037.93	
3,331.52	6	30,007.73	6– 76
3,335.37	7 cw	29,973.09	2– 63
3,337.28	1	29,955.94	
3,338.18	60	29,947.86	18–107
3,339.69	4 c	29,934.32	
3,340.29	1	29,928.94	
3,341.01	1	29,922.50	
3,342.25	50	29,911.39	18–106
3,344.33	30	29,892.79	18–105
3,346.19	20	29,876.18	5– 73
3,346.60	1	29,872.52	
3,347.58	2 c	29,863.77	
3,349.90	2	29,843.09	9– 79
3,351.17	1	29,831.78	
3,351.94	1	29,824.93	
3,353.21	4 c	29,813.63	12– 86
3,355.29	5 c	29,795.15	
3,355.63	2	29,792.13	
3,355.90	2	29,789.74	
3,356.34	4	29,785.83	
3,356.46	3	29,784.76	12– 85
3,356.81	1	29,781.66	
3,358.03	5	29,770.84	
3,358.57	2	29,766.05	14– 91
3,359.21	4	29,760.38	20–115
3,359.80	2	29,755.16	13– 88
3,361.14	4	29,743.30	5– 72
3,361.84	1	29,737.10	
3,362.75	6	29,729.06	2– 61
3,363.03	2	29,726.58	
3,365.74	3	29,702.64	
3,365.82	3	29,701.94	
3,366.17	2 cw	29,698.85	3– 62
3,366.89	1	29,692.50	10– 83
3,367.50	3	29,687.12	8– 77
3,367.68	2	29,685.54	
3,368.61	1	29,677.34	
3,370.89	1	29,657.27	
3,377.74	4	29,597.12	
3,379.07	3 cwE	29,585.48	
3,379.71	6 c	29,579.87	2– 60
3,385.76	2	29,527.02	
3,389.42	5	29,495.14	
3,389.77	2	29,492.09	
3,390.26	4 cw	29,487.83	
3,391.22	1	29,479.48	
3,392.37	1	29,469.49	
3,394.13	2	49,454.21	
3,397.20	2	29,427.59	
3,397.69	1	29,423.34	
3,398.80	1	29,413.74	
3,399.29	60 cw	29,409.50	3– 60
3,401.18	2 c?	29,393.16	
3,404.72	10	29,362.60	2– 58
3,405.89	15 c	29,352.51	6–72
3,406.38	1	29,348.29	
3,408.15	1	29,333.05	
3,408.68	4 c	29,328.48	
3,409.83	5	29,318.59	15– 90
3,412.69	1	29,294.02	
3,413.74	3	29,285.01	
3,414.36	1	29,279.70	
3,416.02	1	29,265.47	
3,417.78	6 c	29,250.40	9– 77
3,419.27	1	29,237.66	2– 57
3,419.41	20	29,236.46	6– 71
3,420.76	4 c	29,224.92	2– 55
3,421.58	2	29,217.92	
3,424.61	200 cw v	29,192.06	3– 58
3,426.19	7	29,178.60	15– 89
3,427.61	7 cw	29,166.51	9– 76
3,428.51	1	29,158.86	19–109
3,428.84	1	29,156.05	
3,431.83	1	29,130.65	10– 79
3,432.68	1	29,123.44	
3,433.72	7	29,114.62	
3,433.82	1 E	29,113.77	
3,437.72	8	29,080.74	8– 73
3,440.85	1	29,054.29	
3,441.25	3 c	29,050.91	
3,442.97	2	29,036.40	11– 82
3,444.99	1 h	29,019.36	7– 71
3,446.57	2 c	29,006.07	
3,449.38	10 d, c?	28,982.44	
3,450.09	1 h	28,976.48	
3,450.94	1 h	28,969.34	
3,451.88	600 cWl	28,961.45	1– 23
3,453.29	3	28,949.63	
3,453.50	5	28,947.87	8– 72
3,458.90	2	28,902.68	14– 86
3,460.47	1,000 cWl	28,889.57	1– 22
3,464.72	800 cWl	28,854.13	1– 21
3,465.99	2	28,843.56	13– 92
3,467.96	10 c	28,827.17	18–102
3,468.64	1	28,821.52	
3,470.85	2 h	28,803.17	
3,472.00	2 h c?	28,793.63	
3,472.72	3	28,787.66	8– 70
3,472.87	1	28,786.42	8– 69
3,473.47	2	28,781.44	15– 85
3,474.20	2 h c?	28,775.40	11– 81
3,475.18	2 d	28,767.28	
3,476.02	1	28,760.33	
3,476.44	5	28,756.86	
3,477.14	2	28,751.07	
3,478.57	2 h c?	28,739.25	3– 54
3,480.39	7	28,724.22	13– 82
3,480.86	8	28,720.34	8– 68
3,482.24	4 c	28,708.96	
3,484.37	1	28,691.41	
3,484.72	1	28,688.53	
3,487.52	1 c?	28,665.50	
3,488.85	1 c?	28,654.57	
3,490.86	3	28,638.07	
3,491.43	1	28,633.40	
3,494.73	2	28,606.36	13– 84
3,495.90	3 cWl	28,596.78	
3,499.52	1	28,567.20	
3,502.74	1	28,540.94	

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
3, 503. 06	10	28, 538. 34	10- 77	3, 617. 87	4 cw	27, 632. 72	
3, 503. 73	2 c?	28, 532. 88		3, 621. 46	4 c	27, 605. 33	13- 76
3, 506. 39	2	28, 511. 23	9- 72	3, 622. 21	2 c	27, 599. 61	
3, 510. 89	2	28, 474. 69		3, 625. 90	3	27, 571. 53	10- 68
3, 512. 28	6 cWl	28, 463. 42	13- 81	3, 629. 20	2	27, 546. 46	
3, 515. 02	1	28, 441. 24		3, 634. 24	1	27, 508. 26	
3, 515. 75	1	28, 435. 33		3, 636. 78	1	27, 489. 05	
3, 516. 16	1 c?	28, 432. 01		3, 637. 06	4	27, 486. 93	5- 61
3, 516. 65	8 c?	28, 428. 06		3, 637. 22	1	27, 485. 72	
3, 517. 33	10 c	28, 422. 56		3, 637. 84	15	27, 481. 04	2- 47
3, 520. 72	3 cWl	28, 395. 19	9- 71	3, 639. 14	3 h c?	27, 471. 22	
3, 521. 74	1	28, 386. 97		3, 641. 48	1	27, 453. 57	
3, 522. 17	1	28, 383. 50		3, 642. 98	2	27, 442. 26	3- 43
3, 522. 32	1 c?	28, 382. 29		3, 643. 73	1	27, 436. 61	
3, 526. 74	2	28, 346. 72		3, 645. 59	2 c?	27, 422. 62	
3, 529. 21	3	28, 326. 89		3, 646. 65	2 c?	27, 414. 65	
3, 529. 79	2 c?	28, 322. 23		3. 648. 25	2 c?	27, 402. 62	
3, 530. 90	1 c?	28, 313. 33		3, 649. 49	1 c?	27, 393. 31	
3, 534. 25	1	28, 286. 49		3, 651. 66	5 cw	27, 377. 03	
3, 534. 82	4	28, 281. 93	13- 79	3, 651. 97	20	27, 374. 71	12- 73
3, 536. 16	1	28, 271. 21		3, 653. 18	1 c?	27, 365. 64	
3, 537. 47	15 c	28, 260. 74	2- 52	3, 653. 62	2	27, 362. 35	20-112
3, 539. 33	4	28, 245. 89		3, 654. 36	1	27, 356. 81	20-111
3, 539. 94	2	28, 241. 03		3, 654. 93	1	27, 352. 54	
3, 541. 32	1	28, 230. 02		3, 658. 74	1	27, 324. 06	
3, 543. 68	1	28, 211. 22		3, 660. 52	2 c	27, 310. 77	
3, 544. 35	1	28, 205. 89		3, 662. 13	2	27, 298. 77	
3, 548. 11	1	28, 176. 00		3, 663. 03	1	27, 292. 06	
3, 549. 32	1	28, 166. 39		3, 669. 43	2	27, 244. 46	
3, 549. 89	5	28, 161. 87	3- 53	3, 669. 78	5	27, 241. 86	12- 72
3, 551. 30	6 cw	28, 150. 69		3, 670. 00	2 c	27, 240. 23	3- 46
3, 551. 59	2 d?	28, 148. 39		3, 670. 37	3 c	27, 237. 48	
3, 553. 65	4 c	28, 132. 07	15- 83	3, 670. 53	10	27, 236. 29	6- 62
3, 558. 95	5 c	28, 090. 18	3- 52	3, 672. 40	3	27, 222. 42	8- 64
3, 559. 41	1	28, 086. 55	2- 51	3, 674. 17	1	27, 209. 31	
3, 561. 14	1	28, 072. 91		3, 676. 00	2	27, 195. 77	
3, 562. 46	2	28, 062. 50		3, 676. 57	1	27, 191. 55	
3, 564. 73	3	28, 044. 64		3, 678. 39	2	27, 178. 10	
3, 565. 20	1	28, 040. 94		3, 680. 21	2	27, 164. 66	
3, 566. 86	1 h	28, 027. 89		3, 681. 29	2	27, 156. 69	
3, 568. 24	4 cw	28, 017. 05		3, 686. 45	1	27, 118. 67	
3, 570. 25	5	28, 001. 28		3, 688. 65	1	27, 102. 50	
3, 571. 70	1	27, 989. 91		3, 688. 90	1	27, 100. 67	
3, 572. 81	2	27, 981. 21	12- 77	3, 689. 52	30 cW v?	27, 096. 11	6- 61
3, 577. 34	2	27, 945. 78		3, 690. 38	2	27, 089. 79	
3, 579. 13	10	27, 931. 81	10- 73	3, 691. 39	4	27, 082. 38	
3, 580. 14	20 cw l, E	27, 923. 93		3, 691. 48	40 c	27, 081. 72	12- 70
3, 580. 97	20 c	27, 917. 45	11- 76	3, 692. 12	1	27, 077. 03	
3, 583. 03	40 c	27, 901. 40	3- 50	3, 697. 70	4 cw	27, 036. 17	
3, 585. 03	2 c	27, 885. 84		3, 700. 36	3 cw	27, 016. 74	
3, 585. 33	1	27, 883. 51		3, 701. 17	1 ?	27, 010. 82	
3, 590. 88	2	27, 840. 41		3, 702. 10	1	27, 004. 04	
3, 593. 39	3 c	27, 820. 96		3, 703. 24	20	26, 995. 73	5- 57
3, 595. 16	3	27, 807. 27		3, 704. 46	3	26, 986. 84	
3, 596. 23	2	27, 798. 99	10- 72	3, 704. 85	3 c	26, 984. 00	5- 56
3, 596. 38	4	27, 797. 84	3- 49	3, 705. 01	2	26, 982. 83	5- 55
3, 598. 76	3	27, 779. 45		3, 705. 68	2 c	26, 977. 95	15- 77
3, 604. 40	3 c	27, 735. 98		3, 708. 77	1	26, 955. 47	
3, 606. 55	1	27, 719. 45		3, 709. 93	10	26, 947. 05	6- 60
3, 607. 22	2	27, 714. 30		3, 711. 51	2 c	26, 935. 56	8- 63
3, 608. 68	1 c	27, 703. 09		3, 712. 93	1	26, 925. 28	
3, 610. 49	6 cw	27, 689. 20		3, 713. 16	2 c	26, 923. 61	
3, 615. 36	1	27, 651. 91		3, 715. 02	2	26, 910. 13	
3, 617. 08	20 c	27, 638. 76	10- 70	3, 717. 29	25 cW v	26, 893. 70	15- 76
3, 617. 24	5	27, 637. 53	10- 69	3, 725. 76	100	26, 832. 56	20-108

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination
3, 726. 49	2	26, 827. 30	
3, 726. 72	3 d	26, 825. 65	
3, 727. 50	2	26, 820. 03	
3, 731. 87	4	26, 788. 63	13– 69
3, 732. 28	6	26, 785. 68	9– 64
3, 735. 00	10 cW v	26, 766. 18	3– 44
3, 735. 33	50	26, 763. 81	20–107
3, 736. 85	2 c	26, 752. 93	
3, 739. 59	1	26, 733. 32	
3, 740. 10	40 c	26, 729. 68	{6– 58 {7– 60
3, 740. 41	5	26, 727. 47	20–106
3, 742. 28	3 E	26, 714. 11	
3, 745. 45	20 c	26, 691. 50	8– 61
3, 746. 94	2	26, 680. 89	
3, 749. 02	1	26, 666. 08	
3, 750. 67	1	26, 654. 36	
3, 752. 78	1 ?	26, 639. 37	
3, 755. 63	4	26, 619. 15	
3, 757. 63	4 cw v	26, 604. 98	6– 57
3, 761. 03	1	26, 580. 93	
3, 763. 49	5 cw l	26, 563. 56	7– 59
3, 766. 49	3	542. 40	8– 60
3, 768. 25	1	26, 530. 01	
3, 769. 30	1	26, 522. 62	
3, 770. 74	1	26, 512. 49	7– 58
3, 775. 46	1	26, 479. 34	
3, 777. 66	7	26, 463. 92	14– 73
3, 780. 36	2	26, 445. 02	
3, 784. 18	2	26, 418. 33	
3, 787. 21	2	26, 397. 19	
3, 787. 52	30 c	26, 395. 03	9– 62
3, 788. 10	1 h c?	26, 390. 99	
3, 795. 80	4 cW l	26, 337. 46	
3, 796. 60	12 cw v	26, 331. 91	2– 41
3, 797. 59	7	26, 325. 04	8– 58
3, 800. 94	1 cw?	26, 301. 84	
3, 805. 41	1 hc?	26, 270. 95	
3, 807. 75	5	26, 254. 80	9– 61
3, 808. 20	2	26, 251. 70	
3, 810. 10	2	26, 238. 61	15– 72
3, 812. 26	2	26, 223. 74	
3, 812. 82	1	26, 219. 89	
3, 815. 66	6 c	26, 200. 38	8– 57
3, 817. 55	5 cW l	26, 187. 41	8– 55
3, 823. 76	3 cw	26, 144. 88	
3, 827. 03	4 cW l	26, 122. 54	15– 71
3, 827. 63	2	26, 118. 44	
3, 828. 32	6	26, 113. 74	2– 39
3, 829. 81	4 c	26, 103. 58	14– 68
3, 832. 39	2 c	26, 086. 00	
3, 833. 70	10	26, 077. 09	15– 69
3, 834. 23	15	26, 073. 49	10– 64
3, 836. 30	6	26, 059. 42	7– 54
3, 841. 49	2	26, 024. 21	
3, 843. 43	15 cw v	26, 011. 07	3– 40
3, 846. 86	1	25, 987. 88	
3, 848. 96	1	25, 973. 71	
3, 851. 99	3	25, 953. 28	
3, 852. 69	1	25, 948. 56	
3, 855. 93	4 c	25, 926. 76	
3, 860. 85	1	25, 893. 72	19– 93
3, 862. 09	1	25, 885. 40	
3, 863. 15	1	25, 878. 30	
3, 863. 77	2	25, 874. 15	16– 72
3, 864. 76	1	25, 867. 52	
3, 869. 94	15 c	25, 832. 90	11– 65
3, 875. 26	15 c	25, 797. 44	2– 38
3, 876. 88	20 cw v	25, 786. 66	10– 63
3, 878. 86	2	25, 773. 49	
3, 881. 90	4	25, 753. 31	17– 78
3, 887. 49	3	25, 716. 28	
3, 887. 96	3	25, 713. 17	
3, 889. 96	3	25, 699. 95	
3, 891. 39	2	25, 690. 50	
3, 893. 45	1 c?	25, 676. 91	
3, 893. 89	1	25, 674. 01	
3, 895. 42	1	25, 663. 93	
3, 896. 11	4 c	25, 659. 38	
3, 900. 89	4	25, 627. 95	6 52
3, 901. 08	2	25, 626. 69	3– 38
3, 902. 58	1	25, 616. 84	
3, 902. 82	1	25, 615. 27	
3, 905. 12	2	25, 600. 18	
3, 907. 19	1	25, 586. 62	
3, 908. 21	5	25, 579. 94	
3, 910. 21	1	25, 566. 86	
3, 911. 76	1	25, 556. 73	
3, 913. 92	5	25, 542. 62	10– 61
3, 915. 22	1	25, 534. 14	
3, 917. 27	25 cw	25, 520. 78	13– 65
3, 919. 10	2 c	25, 508. 86	
3, 920. 86	5 cW v	25, 497. 42	
3, 921. 78	2	25, 491. 43	
3, 922. 27	2	25, 488. 25	
3, 923. 59	1 cw ?	25, 479. 67	2– 37
3, 924. 09	2 c	25, 476. 43	
3, 924. 65	1 h	25, 472. 79	
3, 926. 53	1	25, 460. 60	
3, 926. 84	1	25, 458. 59	
3, 927. 60	10 cW v	25, 453. 66	6– 51
3, 928. 71	2	25, 446. 47	4– 39
3, 929. 20	1	25, 443. 30	
3, 929. 85	25	25, 439. 09	6– 50
3, 930. 52	1 h	25, 434. 75	
3, 931. 20	3	25, 430. 35	19– 92
3, 934. 23	1	25, 410. 77	7– 52
3, 936. 91	10 c	25, 393. 47	10– 60
3, 941. 52	3 d, c?	25, 363. 77	
3, 942. 56	2	25, 357. 08	
3, 944. 35	2	25, 345. 57	
3, 944. 73	6 c	25, 343. 13	
3, 945. 91	10 c	25, 335. 55	6– 49
3, 950. 60	4 d, c?	25, 305. 48	
3, 953. 24	1	25, 288. 58	
3, 954. 43	3 c?	25, 280. 97	
3, 954. 97	5	25, 277. 51	
3, 957. 37	2	25, 262. 18	
3, 958. 36	2	25, 255. 87	
3, 958. 57	1	25, 254. 53	
3, 960. 57	2	25, 241. 77	
3, 961. 04	15	25, 238. 78	5– 47
3, 962. 49	40 cW v	25, 229. 54	12– 63
3, 963. 27	4	25, 224. 58	13– 64
3, 963. 70	2	25, 221. 84	7– 50
3, 964. 27	1	25, 218. 22	
3, 964. 81	3	25, 214. 78	
3, 967. 41	5 cw	25, 198. 26	
3, 967. 70	1	25, 196. 42	
3, 975. 40	1	25, 147. 61	
3, 975. 66	3	25, 145. 97	11– 62

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination
3,976.77	1 h	25,138.95	
3,978.62	4 c	25,127.26	
3,982.28	1 h	25,104.17	17– 75
3,983.43	1 h c?	25,096.92	
3,983.92	3 c	25,093.83	
3,984.25	4 c, E	25,091.76	
3,987.08	2	25,073.95	
3,987.91	1	25,068.73	
3,990.67	2	25,051.39	10– 57
3,991.05	4 cw	25,049.00	8– 51
3,991.58	2 c	25,045.68	
3,992.73	3 cw	25,038.47	10– 55
3,994.15	1 hc?	25,029.56	
3,995.68	3 c	25,019.98	
3,996.92	1 c?	25,012.22	
4,000.13	1 h	24,992.15	
4,001.18	1	24,985.59	12– 61
4,004.94	5	24,962.13	
4,010.31	1	24,928.71	
4,011.52	6	24,921.19	
4,012.26	4	24,916.59	
4,014.88	2	24,900.33	
4,018.41	4 c	24,878.46	
4,019.13	2	24,874.00	19– 90
4,022.95	8	24,850.38	17– 74
4,023.33	10 cW v	24,848.04	6– 47
4,025.07	1	24,837.29	
4,025.62	2	24,833.90	13– 62
4,026.71	1	24,827.18	
4,027.13	1	24,824.59	
4,028.55	4 c	24,815.83	
4,029.62	15 cW l	24,809.25	5–45? 15– 65
4,031.31	1 c?	24,798.85	
4,031.62	1	24,796.94	
4,032.15	2	24,793.68	
4,033.31	30 cw l	24,786.55	9– 52
4,033.62	2 c	24,784.65	
4,037.51	6	24,760.77	
4,039.51	1	24,748.51	
4,040.19	2	24,744.35	
4,041.31	1	24,737.49	
4,045.25	1	24,713.39	
4,048.99	10 c	24,690.57	11– 59
4,050.93	1	24,678.74	
4,061.66	1	24,613.55	
4,061.86	3	24,612.34	9– 51
4,064.31	2	24,597.50	9– 50
4,064.92	1 c?	24,593.81	
4,066.96	1	24,581.47	
4,067.24	1	24,579.78	
4,069.15	3 c, E	24,568.25	
4,073.05	1	24,544.72	13– 60
4,073.22?	8	24,543.70	
4,078.12	2	24,514.21	
4,079.37	3	24,506.69	
4,081.43	12	24,494.33	12– 57
4,083.37	4	24,482.69	12– 56
4,083.60	4	24,481.31	12– 55
4,088.03	2 c	24,454.78	18– 80
4,089.00	2	24,448.98	
4,089.41	1	24,446.53	
4,089.92	5 c v	24,443.48	8– 47
4,091.10	1	24,436.43	
4,091.96	1 E	24,431.30	
4,092.94	1 h	24,425.45	

Wave length	Intensity and character	Vacuum wave number	Combination
4,096.45	1	24,404.52	
4,099.30	1 ?	24,387.55	
4,102.16	3 h	24,370.55	
4,103.78	1	24,360.93	
4,104.42	12	24,357.13	
4,106.44	3 c	24,345.15	
4,106.83	2	24,342.84	
4,107.44	1	24,339.22	
4,107.95	1	24,336.20	
4,108.61	3	24,332.29	
4,110.90	30 cwv	24,318.74	14– 63
4,111.58	2 d v	24,314.71	
4,112.26	2	24,310.69	
4,113.41	8	24,303.90	6– 44
4,114.68	1	24,296.40	
4,121.60	25	24,255.60	18– 78
4,122.75	2	24,248.84	
4,123.51	1	24,244.37	
4,123.82	1	24,242.55	
4,124.78	3 hc?	24,236.90	
4,128.09	2 d?	24,217.47	
4,130.46	2	24,203.57	
4,132.30	6	24.192.80	5– 42
4,133.42	80 cW, d	24,186.24	11– 54
4,136.45	100	24,168.52	3– 36
4,137.59	5	24,161.86	19– 84
4,138.52	1	24,156.44	
4,142.44	1 h	24,133.58	
4,142.77	1	24,131.66	
4,144.36	60	24,122.40	15– 62
4,146.24	3	24,111.46	
4,148.29	2	24,099.55	
4,149.98	20 c	24,089.73	5– 41
4,150.54	2	24,086.48	
4,150.80	1	24,084.97	
4,151.06	1	24,083.46	
4,152.30	3	24,076.27	
4,152.64	8 c	24,074.30	10– 52
4,157.23	1	24,047.72	
4,159.92	4	24,032.17	
4,160.77	2	24,027.26	
4,161.77	1	24,021.49	
4,164.09	1	24,008.11	
4,165.32	1	24,001.02	
4,165.98	1	23,997.21	
4,166.41	2	23,994.74	
4,168.58	3	23,982.25	15– 61
4,170.40	15	23,971.78	
4,173.69	1	23,952.88	
4,173.99	3	23,951.16	
4,175.19	3	23,944.28	
4,176.54	3 c	23,936.54	9– 46
4,176.88	2	23,934.59	
4,178.61	2	23,924.68	
4,178.85	1	23,923.31	
4,179.74	1	23,918.22	
4,182.22	1	23,904.03	
4,182.98	50 cw	23,899.69	8–44?
4,184.50	1	23,891.01	
4,185.72	1 h	23,884.04	
4,187.91	2	23,871.55	5– 39
4,188.46	1	23,868.42	
4,190.79	1 h	23,855.15	
4,191.90	2	23,848.83	
4,194.67	12 c	23,833.08	15– 60

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
4,195.75	4	23,826.95		4,316.19	2	23,162.09	
4,203.32	2 c?	23,784.04		4,317.13	2 h	23,157.05	
4,204.55	8 c	23,777.08		4,317.68	1	23,154.10	
4,215.50	2	23,715.32		4,317.94	1	23,152.70	
4,221.08	30	23,683.97	2- 34	4,318.58	4	23,149.27	
4,224.17	3	23,666.65	15- 59	4,319.54	5	23,144.13	8- 40
4,227.45	200 c	23,648.28	17- 67	4,324.35	2	23,118.38	
4,228.74	1	23,641.07		4,328.70	2	23,095.15	
4,232.96	4	23,617.50	16- 61	4,329.07	2	23,093.18	
4,233.28	3	23,615.72	15- 58	4,331.37	2	23,080.91	
4,234.43	2 c?	23,609.30	11- 53	4,332.25	30	23,076.23	8- 39
4,234.98	4 c	23,606.24	18- 75	4,335.86	3	23,057.02	
4,235.40	1 ?	23,603.90		4,339.69	4	23,036.67	13- 50
4,236.24	4	23,599.22		4,342.16	2	23,023.56	
4,238.02	2	23,589.31		4,344.66	1 c?	23,010.31	
4,238.59	3	23,586.13	17- 66	4,345.50	1	23,005.87	
4,239.97	1	23,578.45		4,351.72	1	22,972.98	
4,241.17	6	23,571.78	14- 56	4,352.44	2 hc?	22,969.19	
4,241.39	15	23,570.56	14- 55	4,357.07	4 c	22,944.77	
4,241.81	1	23,568.23	19- 82	4,357.96	5	22,940.09	
4,243.90	1	23,556.62		4,358.69	50	22,936.25	2- 31
4,244.15	5 c	23,555.23	5- 38	4,359.31	3	22,932.99	13- 49
4,246.82	7	23,540.43		4,360.38	4	22,927.36	
4,247.70	1	23,535.55		4,361.28	2	22,922.63	
4,248.36	1	23,531.89		4,363.36	2 c	22,911.70	
4,255.12	1	23,494.51		4,364.13	4	22,907.66	
4,255.34	1	23,493.29		4,364.84	3	22,903.93	
4,255.76	5	23,490.98	15- 57	4,366.35	1	22,896.01	
4,257.61	50 c	23,480.77	6- 39	4,367.57	30 c	22,889.62	11- 48
4,258.88	1	23,473.77		4,369.65	1	22,878.72	
4,259.89	2	23,468.20	16- 60	4,369.76	2	22,878.14	4- 33
4,260.92		23,462.53	9- 44	4,373.20	2	22,860.15	
4,261.28	2	23,460.55		4,377.07	1	22,839.94	
4,261.44	1 c?	23,459.67		4,377.45	2	22,837.95	
4,263.36	1	23,449.10		4,378.46	1	22,832.69	
4,263.78	1	23,446.79		4,380.89	1 h	22,820.02	
4,264.26	1	23,444.15		4,385.44	4	22,796.35	
4,264.74	1	23,441.51		4,386.11	1 h	22,792.86	
4,267.99	1 c?	23,423.66		4,387.41	4 c	22,786.11	
4,268.73	2 c	23,419.60		4,387.92	1 h	22,783.46	
4,269.81	2	23,413.68		4,388.55	1 h	22,780.19	
4,274.35	3 c	23,388.81		4,391.35	40 c	22,765.67	3- 31
4,279.19	1	23,362.35		4,392.15	1	22,761.52	
4,280.61	2	23,354.61		4,392.47	30 cw	22,759.86	8- 38
4,281.70	1 h	23,348.66	11- 50	4,394.37	80 c	22,750.02	10- 44
4,282.74	3	23,342.99	12- 51	4,396.09	5	22,741.12	
4,286.09	1	23,324.75		4,396.79	10	22,737.50	12- 47
4,286.47	2	23,322.68		4,397.83	1	22,732.12	
4,291.18	30 cw	23,297.08	13- 53	4,399.82	3 c	22,721.84	
4,291.64	10	23,294.58	{ 8- 41 10- 47	4,402.60	15	22,707.49	9- 40
4,291.77	2	23,293.88		4,403.68	2	22,701.92	
4,298.21	2 h	23,258.98		4,404.28	1	22,698.83	
4,299.92	4, E?	23,249.73		4,406.40	30 cw	22,687.91	11- 46
4,301.07	2	23,243.51		4,408.67	1 h	22,676.23	
4,301.79	1	23,239.62		4,410.39	1	22,667.39	
4,302.17	2 d?	23,237.57	5- 37	4,412.52	1	22,656.45	
4,304.41	30	23,225.48	13- 52	4,413.50	1	22,651.41	
4,304.77	1	23,223.53		4,415.82	30	22,639.51	9- 39
4,305.34	5	23,220.46		4,417.28	5 c	22,632.03	
4,308.79	2	23,201.87		4,418.81	3	22,624.19	
4,309.48	3	23,198.15		4,419.86	1	22,618.82	
4,310.44	1	23,192.99		4,423.00	2, E?	22,602.76	
4,313.33	1	23,177.45		4,423.81	1	22,598.62	
4,314.58	5	23,170.74		4,425.77	2	22,588.62	
4,315.74	10 cW	23,164.51	6- 38	4,426.47	1 h	22,585.04	

TABLE 1.—*The arc spectrum of rhenium* (Re_{I})—Continued

Wave length	Intensity and character	Vacuum wave number	Combination
4,427.67	1	22,578.92	
4,427.95	4 c	22,577.50	13- 48
4,428.86	1	22,572.86	
4,432.83	1	22,552.64	
4,434.23	1	22,545.52	
4,436.62	2	22,533.38	19- 77
4,440.44	15 cw	22,513.99	15- 52
4,446.00	1 h	22,485.84	
4,448.15	1	22,474.97	
4,448.26	2	22,474.41	
4,453.88	8	22,446.05	
4,454.65	50 cW	22,442.17	8- 37
4,456.38	2	22,433.46	
4,456.69	3	22,431.90	
4,457.48	2	22,427.93	
4,458.13	1	22,424.66	
4,459.39	1	22,418.32	
4,463.51	6	22,397.63	
4,464.62	2	22,392.06	
4,465.84	2	22,385.94	
4,467.55	6	22,377.37	
4,467.93	15 c	22,375.47	13- 46
4,473.24	1	22,348.91	
4,473.92	1	22,345.51	
4,475.09	25	22,339.67	15- 51
4,477.64	2	22,326.95	
4,477.99	10 c	22,325.20	15- 50
4,478.39	25	22,323.21	
4,481.45	4	22,307.97	12- 45
4,486.58	2 c?	22,282.46	
4,487.00	2	22,280.38	
4,494.10	2	22,245.18	
4,495.10	1 h	22,240.23	
4,496.44	6	22,233.60	9- 38
4,498.38	3	22,224.01	
4,499.04	1	22,220.75	
4,504.42	2	22,194.21	4- 30
4,507.03	40	22,181.36	21-114
4,507.99	20	22,176.64	21-113
4,513.31	300 c	22,150.50	18- 67
4,514.27	5	22,145.78	{10- 41 22-114
4,515.13	3	22,141.57	
4,515.90	1	22,137.79	
4,516.63	50	22,134.21	21-111
4,518.57	1	22,124.71	
4,519.76	20 c	22,118.89	21-110
4,522.71	100	22,104.46	22-112
4,523.87	30	22,098.79	22-111
4,525.97	30 c	22,088.54	18- 66
4,526.95	4 hc?	22,083.76	
4,528.95	15	22,074.00	23-114
4,529.92	40 c	22,069.28	23-113
4,530.89	10	22,064.55	
4,531.36	1	22,062.26	
4,536.01	10	22,039.65	
4,537.55	2	22,032.17	
4,539.10	2 cw	22,024.64	
4,541.81	15	22,011.50	23-110
4,545.16	30	21,995.28	10- 40
4,545.53	3	21,993.49	
4,549.20	2	21,975.75	
4,550.49	2 cw, E	21,969.52	
4,551.49	2	21,964.69	
4,556.01	2	21,942.90	
4,557.31	2 c	21,936.64	

Wave length	Intensity and character	Vacuum wave number	Combination
4,559.25	10	21,927.31	10- 39
4,559.69	15	21,925.19	5- 35
4,562.30	1	21,912.65	
4,563.23	1	21,908.18	
4,563.63	3 c?	21,906.26	
4,564.62	2	21,901.51	13- 44
4,565.31	10	21,898.20	
4,565.49	15	21,897.34	12- 43
4,568.74	1 h	21,881.76	
4,571.91	1 c?	21,866.59	
4,572.18	2	21,865.30	
4,574.39	1 h	21,854.73	
4,575.01	2	21,851.77	
4,575.99	2 hc?	21,847.09	
4,577.53	2	21,839.74	
4,578.24	2	21,836.36	
4,578.92	1	21,833.11	
4,580.67	30	21,824.77	2- 26
4,586.06	2 c	21,799.12	
4,587.13	4	21,794.04	19- 72
4,588.95	2	21,785.39	
4,590.56	1 h	21,777.75	
4,591.67	8	21,772.49	
4,592.54	3	21,768.36	
4,595.25	2	21,755.53	
4,597.31	3 c?	21,745.78	
4,598.14	3	21,741.85	
4,599.76.	1	21,734.19	15- 47
4,605.72	50	21,706.07	6- 36
4,607.79	1 h	21,696.32	
4,608.80	3	21,691.56	12- 42
4,609.80	1	21,686.86	
4,613.06	1	21,671.53	
4,613.96	2	21,667.31	
4,614.68	12 cw	21,663.93	15- 46
4,616.61	8 cw	21,654.87	
4,619.76	1 h	21,640.10	
4,621.39	25	21,632.47	19- 69
4,623.34	2	21,623.35	
4,424.73	1 h	21,616.85	
4,625.98	10 c	21,611.01	10- 38
4,628.75	1	21,598.08	
4,630.24	4 c	21,591.13	
4,630.83	30 c	21,588.37	12- 41
4,634.40	4 cw	21,571.74	
4,635.78	2	21,565.32	
4,640.34	1	21,544.13	
4,640.91	1	21,541.49	
4,641.38	1	21,539.31	
4,642.70	2 h	21,533.18	
4,644.95	6 c	21,522.75	
4,646.26	1	21,516.68	
4,647.47	4 c	21,511.08	
4,648.58	3	21,505.94	22-107
4,649.20	1	21,503.08	
4,649.73	2	21,500.62	
4,650.08	2	21,499.01	
4,650.83	2	21,495.54	
4,651.19	1	21,493.88	
4,651.82	2	21,490.97	
4,652.32	3 c	21,488.66	7- 36
4,652.81	1 h	21,486.39	21-105
4,654.56	4 c	21,478.32	21-104
4,656.49	5 d	21,469.41	22-106
4,657.33	1	21,465.54	

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
4, 660. 53	4	21, 450. 80	22–105	4, 806. 03	1 h	20, 801. 40	
4, 661. 48	3	21, 446. 43		4, 810. 10	3	20, 783. 80	
4, 662. 49	10	21, 441. 78	5– 34	4, 811. 20	3	20, 779. 04	
4, 663. 00	2 h	21, 439. 44		4, 813. 13	2	20, 770. 71	
4, 665. 23	2	21, 429. 19		4, 814. 89	1 h	20, 763. 12	
4, 666. 72	2	21, 422. 35		4, 816. 05	2 h	20, 758. 12	
4, 674. 31	4	21, 387. 56		4, 818. 40	1	20, 748. 00	
4, 675. 39	2	21, 382. 62		4, 819. 25	1 h	20, 744. 34	
4, 679. 48	4	21, 363. 94		4, 820. 59	10 cw	20, 738. 57	
4, 681. 89	1	21, 352. 94		4, 822. 64	1 h	20, 729. 76	
4, 682. 32	15	21, 350. 98		4, 825. 12	1	20, 719. 10	
4, 685. 18	1 h	21, 337. 94	4– 28	4, 829. 89	3 cw	20, 698. 64	
4, 687. 85	5	21, 325. 79		4, 831. 95	1 h	20, 689. 82	
4, 688. 82	1 h	21, 321. 38		4, 832. 90	1	20, 685. 75	
4, 689. 55	2	21, 318. 06		4, 833. 98	2 c	20, 681. 12	
4, 691. 45	2	21, 309. 43		4, 834. 82	4 c	20, 677. 53	14– 41
4, 692. 83	1	21, 303. 16	5– 33	4, 838. 83	1	20, 660. 40	
4, 693. 39	3	21, 300. 62		4, 839. 63	4	20, 656. 98	
4, 695. 01	15 cw	21, 293. 27	10– 37	4, 843. 45	1	20, 640. 69	
4, 698. 08	1	21, 279. 36		4, 843. 74	1	20, 639. 46	
4, 699. 69	2	21, 272. 07		4, 845. 68	2	20, 631. 19	
4, 700. 44	10	21, 268. 67		4, 846. 27	2	20, 628. 68	
4, 703. 77	2 h	21, 253. 62		4, 848. 47	10 cw	20, 619. 32	5– 30
4, 704. 12	1	21, 252. 03		4, 849. 23	1	20, 616. 09	
4, 705. 05	20 c	21, 247. 83		4, 852. 58	3 c	20, 601. 85	6– 32
4, 711. 24	1	21, 219. 92		4, 854. 08	1	20, 595. 49	
4, 712. 77	6 c	21, 213. 03		4, 856. 72	1	20, 584. 30	
4, 725. 02	3 cw	21, 158. 03		4, 857. 15	5	20, 582. 47	
4, 725. 94	7	21, 153. 91		4, 862. 54	2	20, 559. 66	
4, 727. 60	25	21, 146. 48	13– 40	4, 863. 07	2	20, 557. 42	
4, 730. 42	2 h	21, 133. 88		4, 864. 42	1 h	20, 551. 71	
4, 731. 82	2	21, 127. 63		4, 866. 56	1	20, 542. 68	
4, 733. 87	3	21, 118. 47		4, 868. 44	1	20, 534. 74	
4, 735. 34	1	21, 111. 92		4, 869. 70	4 cW l	20, 529. 43	16– 43
4, 738. 54	1	21, 097. 67		4, 872. 07	1 h	20, 519. 44	
4, 743. 52	3 d	21, 075. 52		4, 872. 45	1	20, 517. 84	
4, 746. 25	2 h	21, 063. 39		4, 874. 84	3	20, 507. 78	8– 33
4, 748. 07	3	21, 055. 32		4, 876. 93	2	20, 498. 99	
4, 748. 39	25 c	21, 053. 90	12– 38	4, 881. 27	1	20, 480. 77	
4, 749. 03	10	21, 051. 06	6– 34	4, 882. 95	2	20, 473. 72	
4, 751. 00	3	21, 042. 33		4, 889. 15	2, 000 cW l	20, 447. 76	1– 18
4, 751. 36	4 hc?	21, 040. 74		4, 892. 24	1	20, 434. 84	15– 40
4, 752. 10	2	21, 037. 46		4, 896. 17	2	20, 418. 44	
4, 758. 86	15	21, 007. 58	2– 25	4, 899. 42	2	20, 404. 90	
4, 759. 52	1	21, 004. 67		4, 899. 66	2	20, 403. 89	
4, 761. 03	1	20, 998. 00		4. 901. 43	2	20, 396. 53	
4, 762. 29	1	20, 992. 45	5– 32	4, 903. 73	6 cw	20, 386. 96	
4, 763. 68	10 c	20, 986. 32	14– 43	4, 904. 77	1	20, 382. 64	
4, 766. 91	1	20, 972. 10		4, 906. 22	5	20, 376. 62	
4, 771. 80	2	20, 950. 61		4, 908. 56	8	20, 366. 90	15– 39
4, 777. 13	1	20, 927. 24		4, 909. 05	2 cw	20, 364. 87	19– 65
4, 779. 00	2	20, 919. 05		4, 914. 36	2	20, 342. 86	
4, 781. 83	1	20, 906. 67		4, 915. 02	25	20, 340. 13	4– 25
4, 788. 72	1	20, 876. 59		4, 917. 84	3 c	20, 328. 47	
4, 789. 21	3	20, 874. 45		4, 922. 37	1	20, 309. 76	
4, 791. 42	100 c	20, 864. 83	9– 36	4, 923. 91	100 c	20, 303. 41	6– 31
4, 793. 57	1	20, 855. 46		4, 925. 99	1	20, 294. 84	
4, 796. 91	2	20, 841. 95		4, 926. 91	3	20, 291. 05	
4, 799. 13	4	20, 831. 31		4, 928. 60	1 hc?	20, 284. 09	
4, 799. 50	3	20, 829. 70		4, 932. 37	2	20, 268. 59	
4, 800. 78	2 cw	20, 824. 15		4, 933. 74	7c	20, 262. 96	
4, 802. 29	1	20, 817. 60		4, 935. 85	8	20, 254. 30	
4, 803. 34	1	20, 813. 05		4, 938. 64	1 h	20, 242. 86	
4, 805. 19	1	20, 805. 04		4, 943. 73	3 c	20, 222. 01	
4, 805. 54	1	20, 803. 52		4, 944. 88	3	20, 217. 31	

TABLE 1.—*The arc spectrum of rhenium* (*Re* I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
4,946.73	50	20,209.75	9– 34	5,120.32	12	19,524.60	
4,949.83	5	20,197.09	8– 32	5,124.20	1	19,509.82	
4,952.26	1	20,187.18		5,124.59	4	19,508.34	
4,955.29	2	20,174.84		5,126.68	10 c W l	19,500.38	
4,956.77	20	20,168.82	20– 74	5,140.03	3	19,449.74	
4,960.42	1	20,153.98		5,141.27	2	19,445.04	
4,961.39	4	20,150.04		5,145.58	3	19,428.76	
4,963.07	4 c	20,143.22	14– 38	5,146.90	6 cw	19,423.78	12– 35
4,967.82	3	20,123.96		5,156.25	4 c	19,388.55	19– 60
4,969.44	4	20,117.39		5,161.64	6	19,368.31	16– 37
4,972.84	4	20,103.64		5,165.19	2	19,355.00	
4,974.67	2	20,096.25		5,167.89	1	19,344.89	
4,976.94	1	20,087.08		5,172.38	1	19,328.09	
4,980.68	3 c	20,072.00	5– 29	5,172.72	3 c	19,326.82	
4,981.54	6	20,068.53	19– 64	5,178.89	15 cw	19,303.79	13– 36
4,984.81	2	20,055.37		5,181.74	5	19,293.18	
4,985.99	40 c	20,050.62	15– 38	5,185.88	1	19,277.78	
4,987.52	2	20,044.47		5,186.14	1	19,276.81	8– 29
4,994.03	2	20,018.34		5,186.42	1	19,275.77	
4,996.42	1	20,008.76		5,199.88	2 h	19,225.87	
4,997.74	2	20,003.48		5,200.84	1 h	19,222.32	19– 59
4,999.39	2	19,996.88		5,214.72	2	19,171.16	19– 58
5,003.59	5	19,980.09		5,217.44	1	19,161.17	
5,008.15	3 c	19,961.90		5,218.22	2	19,158.30	
5,010.57	2	19,952.26		5,221.14	2 h	19,147.59	
5,011.87	1	19,947.08		5,222.11	2	19,144.03	
5,017.74	1	19,923.75		5,224.73	6+Ag g	19,134.43	
5,024.01	1	19,898.89	8– 31	5,234.31	5 c	19,099.41	
5,026.44	6	19,889.26		5,236.65	4 c	19,090.88	
5,027.93	5	19,883.37		5,244.32	3	19,062.96	
5,029.77	1 h	19,876.10		5,245.50	1 h	19,058.67	
5,031.56	1	19,869.03		5,248.85	8	19,046.51	19– 57
5,031.04	1	19,867.53		5,250.05	2 h	19,042.15	
5,036.84	1	19,848.20		5,252.33	2	19,033.89	
5,041.39	1 h	19,830.28		5,260.59	2 c v?	19,004.00	
5,042.63	4 cw	19,825.41	14– 37	5,262.37	2 h c?	18,997.57	
5,052.21	2 h	19,787.82		5,264.40	2	18,990.25	
5,054.36	1	19,779.40		5,264.40	2	18,990.25	
5,054.95	1	19,777.09		5,265.12	2	18,987.65	
5,056.05	3	19,772.79		5,270.96	500 c	18,966.61	20– 67
				5,275.54	1,000 cW l	18,950.15	1– 17
5,058.55	25	19,763.02	5– 28	5,278.24	30	18,940.45	12– 34
5,060.43	3	19,755.67		5,279.07	1	18,937.47	
5,063.74	3	19,742.76		5,284.58	2	18,917.73	
5,065.30	2	19,736.68		5,286.76	1 h	18,909.93	
5,067.53	2	19,728.00		5,287.92	3 c	18,905.78	
5,068.88	2 h	19,722.74		5,291.37	2 cw	18,893.45	
5,072.72	1 h	19,707.81		5,292.27	2	18,890.24	
5,078.40	3	19,685.77	16– 38	5,296.70	1 cw	18,874.44	
5,081.58	1	19,673.45		5,300.76	3 c?	18,859.99	
5,087.64	1	19,650.02		5,305.56	10	18,842.92	
5,090.55	3	19,638.78		5,306.72	2	18,838.80	
5,093.18	2	19,628.64		5,309.89	1	18,827.55	
5,094.03	2	19,625.37		5,311.53	3 c	18,821.74	
5,095.77	4 d v	19,618.67		5,317.28	8 c	18,801.39	
5,096.48	30 c	19,615.93	11– 36	5,319,24	1	18,794.46	
5,098.75	1	19,607.20		5,321.27	10	18,787.30	8– 26
5,100.69	1	19,599.75		5,321.50	1	18,786.48	
5,104.63	8 cw	19,584.62	5– 27	5,325.19	1 v n?	18,773.46	
5,105.14	3	19,582.66	5– 26	5,327.46	30	18,765.46	5– 25
5,108.76	4	19,568.78		5,331.88	15 c	18,749.91	10– 31
5,112.25	6	19,555.43		5,332.48	1 ?	18,747.80	
5,113.24	1	19,551.64		5,332.76	4	18,746.81	
5,115.21	1 h c?	19,544.11		5,333.85	8	18,742.98	
5,116.88	1	19,537.73	19– 61	5,338.62	3	18,726.24	
5,117.40	1	19,535.74		5,339.40	3	18,723.50	

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
5, 342. 35	2	18, 713. 16		5, 612. 27	4 c	17, 813. 17	
5, 343. 72	2 c?	18, 708. 37		5, 619. 76	2	17, 789. 43	
5, 345. 20	1	18, 703. 19		5, 621. 20	1	17, 784. 87	
5, 349. 23	2	18, 689. 10		5, 625. 45	3 c	17, 771. 43	
5, 350. 43	3 cw	18, 684. 90		5, 635. 45	1	17, 739. 90	
5, 352. 62	1	18, 677. 26		5, 644. 46	2	17, 711. 58	
5, 353. 30	2	18, 674. 89		5, 653. 02	4	17, 684. 76	
5, 353. 71	1	18, 673. 46		5, 658. 69	2 h	17, 667. 04	
5, 356. 66	1	18, 663. 17		5, 662. 86	2 c	17, 654. 03	
5, 366. 64	1	18, 628. 47		5, 664. 71	2	17, 648. 27	
5, 369. 45	10	18, 618. 72		5, 665. 03	1	17, 647. 27	
5, 369. 80	10	18, 617. 50	5– 24	5, 667. 88	40	17, 638. 40	10– 26
5, 374. 69	3	18, 600. 56		5, 671. 04	2	17, 628. 57	
5, 377. 08	100 cw l	18, 592. 30	15– 36	5, 672. 68	1 c?	17, 623. 47	
5, 378. 15	3	18, 588. 60		5, 680 92	2	17, 597. 91	
5, 379. 69	2	18, 583. 28		5, 684. 32	1	17, 587. 39	
5, 390. 20	1 ?	18, 547. 04		5, 689. 75	3 c	17, 570. 60	12– 29
5, 396. 47	4	18, 525. 50		5, 706. 51	2	17, 519. 00	
5, 402. 18	2	18, 505. 92		5, 711. 43	8	17, 503. 90	
5, 409. 50	1	18, 480. 87		5, 714. 03	3	17, 495. 94	
5, 410. 00	1 c?	18, 479. 16		5, 716. 96	6	17, 486. 98	
5, 416. 26	1	18, 457. 81		5, 725. 64	4	17, 460. 46	
5, 417. 74	2 c	18, 452. 77		5, 727. 89	2	17, 453. 60	
5, 420. 44	1 h?	18, 443. 57		5, 732. 26	1 ?	17, 440. 30	
5, 421. 75	2	18, 439. 12		5, 733. 05	3 c ?	17, 437. 90	
5, 423. 28	1	18, 433. 92		5, 734. 28	2 hc	17, 434. 16	16– 33
5, 423. 59	3	18, 432. 86		5, 734. 80	1	17, 432. 58	
5, 423. 77	3	18, 432. 25		5, 736. 27	1	17, 428. 11	
5, 431. 87	8	18, 404. 76		5, 737. 35	1 hc ?	17, 424. 83	
5, 437. 01	4	18, 387. 36		5, 738. 08	1 c ?	17, 422. 61	
5, 437. 39	1	18, 386. 08		5, 739. 44	3	17, 418. 48	
5, 447. 89	4	18, 350. 64	9– 26	5, 740. 29	5 cW l	17, 415. 90	
5, 449. 65	1	18, 344. 72		5, 752. 92	100 cw l	17, 377. 67	2– 23
5, 456. 28	1	18, 322. 42		5, 763. 40	1 ?	17, 346. 07	
5, 460. 62	4	18, 307. 86		5, 776. 81	200 cW l	17, 305. 80	2– 22
5, 480. 99	2	18, 239. 82		5, 778. 30	2 d v ?	17, 301. 34	
5, 495. 70	1 h?	18, 191. 00		5, 783. 01	1	17, 287. 25	
5, 501. 91	3	18, 170. 47		4, 786. 21	4 c v	17, 277. 69	
5, 505. 64	2 h	18, 158. 16		5, 791. 59	7	17, 261. 64	12– 28
5, 519. 52	2 c	18, 112. 50		5, 796. 25	1	17, 247. 76	
5, 520. 04	4 c	18, 110. 79		5, 806. 96	5	17, 215. 95	
5, 521. 09	6	18, 107. 35		5, 807. 42	2 hc	17, 214. 59	
5, 521. 82	1 c?	18, 104. 95		5, 808. 84	5 c	17, 210. 38	
5, 523. 41	5 cw	18, 099. 74		5, 810. 66	1 h	17, 204. 99	
5, 524. 22	1 d?	18, 097. 09		5, 810. 96	1	17, 204. 10	
5, 529. 97	1	18, 078. 27		5, 815. 89	8 cw	17, 189. 52	15– 31
5, 532. 67	25 cw	18, 069. 45	19– 52	5, 818. 08	1	17, 183. 05	
5, 535. 93	1 h	18, 058. 81		5, 818. 24	1	17, 182. 58	
5, 540. 13	1 h?	18, 045. 12		5, 834. 31	500	17, 135. 25	3– 22
5, 551. 05	1 h c?	18, 009. 62		5, 835. 48	2 cw	17, 131. 82	
5, 557. 20	3	17, 989. 69		5, 851. 98	10 cW l	17, 083. 51	12– 27
5, 563. 25	50 cw	17, 970. 13	8– 25	5, 852. 73	2	17, 081. 32	12– 26
5, 564. 13	4	17, 967. 28		5, 866. 57	4 c ?	17, 041. 02	
5, 573. 48	8 c	17, 937. 14	15– 34	5, 868. 04	3	17, 036. 75	
5, 577. 70	2 c	17, 923. 57		5, 870. 69	1	17, 029. 06	
5, 580. 77	1	17, 913. 71		5, 904. 00	3	16, 932. 99	
5, 582. 90	1	17, 906. 88		5, 908. 02	1?	16, 921. 47	
5, 584. 72	8 c	17, 901. 04	13– 31	5, 909. 98	3	16, 915. 85	
5, 592. 68	1	17, 875. 56		5, 911. 14	3	16, 912. 54	
5, 594. 86	2	17, 868. 60		5, 916. 61	1 h	16, 896. 90	
5, 601. 91	2	17, 846. 11		5, 919. 85	3	16, 887. 65	
5, 604. 16	1	17, 838. 95		5, 927. 38	3 cw	16, 866. 20	
5, 607. 22	4 d? l	17, 829. 21		5, 943. 24	30	16, 821. 19	10– 25
5, 608. 79	2	17, 824. 23		5, 945. 48	1 h ?	16, 814. 85	
5, 610. 52	2	17, 818. 73	10– 28	5, 947. 57	1	16, 808. 94	

TABLE 1.—*The arc spectrum of rhenium* (Re_I)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
5, 950. 21	4 c	16, 801. 48		6, 557. 65	2 c ?	15, 245. 16	
5, 954. 29	2	16, 789. 97		6, 577. 12	15 cW v	15, 200. 03	21– 75
5, 956. 07	1	16, 784. 96		6, 592. 54	25 cW	15, 164. 48	22– 75
5, 967. 61	2	16, 752. 50		6, 605. 19	80 d	15, 135. 44	5– 23
5, 969. 76	5 c	16, 746. 46		6, 611. 65	3 c	15, 120. 65	
5, 972. 55	2	16, 738. 64		6, 612. 52	4	15, 118. 66	
5, 981. 65	2 c	16, 713. 18		6, 623. 92	15 c	15, 092. 64	23– 75
5, 982. 67	3	16, 710. 33	4– 23	6, 637. 23	6 cw	15, 062. 37	
5, 983. 14	2	16, 709. 01		6, 652. 36	40 c	15, 028. 12	5– 21
5, 989. 99	3	16, 689. 90		6, 658. 74	1	15, 013. 72	
5, 995. 74	4 c	16, 673. 90		6, 665. 29	8 cW l	14, 998. 96	
6, 029. 05	1 h	16, 581. 78		6, 683. 30	6 c	14, 958. 55	
6, 036. 32	2	16, 561. 81		6, 688. 73	2	14, 946. 40	21– 74
6, 039. 68	3 cw	16, 552. 60		6, 695. 15	2 c ?	14, 932. 07	
6, 051. 16	2	16, 521. 19		6, 711. 29	8 c	14, 896. 16	16– 25
6, 081. 56	1 ?	16, 438. 61		6, 723. 56	1 p ?	14, 868. 98	
6, 114. 20	6	16, 350. 85	14– 28	6, 724. 95	2	14, 865. 90	
6, 125. 44	2	16, 320. 85		6, 751. 22	25	14, 808. 06	
6, 132. 97	2 c	16, 300. 81		6, 761. 19	5 c	14, 786. 22	
6, 145. 80	6 cw	16, 266. 78		6, 799. 57	4 cw	14, 702. 76	
6, 146. 82	8 c	16, 264. 08	12– 25	6, 801. 65	4	14, 698. 26	
6, 169. 58	2 c	16, 204. 09		6, 805. 36	4 c ?	14, 690. 25	
6, 176. 56	2 cw	16, 185. 77		6, 811. 37	2	14, 677. 29	
6, 181. 68	1	16, 172. 37	14– 27	6, 813. 42	200 d l	14, 672. 87	6– 22
6, 187. 90	2	16, 156. 11		6, 816. 40	1	14, 666. 46	
6, 195. 45	4 c v ?	16, 136. 42		6, 829. 96	200 d	14, 637. 34	6– 21
6, 200. 73	1	16, 122. 68		6, 835. 35	2	14, 625. 80	
6, 203. 24	4 c ?	16, 116. 16	12– 24	6, 844. 06	2	14, 607. 19	
6, 217. 98	6	16, 077. 95	15– 26	6, 844. 44	2	14, 606. 38	
6, 218. 76	1 hc ?	16, 075. 94		6, 874. 38	3	14, 542. 76	
6, 229. 44	8 cW v	16, 048. 38	21– 80	6, 882. 1	1	14, 526. 4	
6, 243. 28	10 cW v	16, 012. 80	22– 80	6, 963. 57	1	14, 356. 50	
6, 247. 58	1 d	16, 001. 78		6, 967. 67	3	14, 348. 05	
6, 252. 06	1	15, 990. 31	19– 40	6, 971. 52	100 c	14, 340. 13	8– 23
6, 253. 02	2	15, 987. 86		6, 976. 68	1	14, 329. 52	
6, 260. 04	4 c ?	15, 969. 93		6, 985. 19	10 cW	14, 312. 06	
6, 260. 24	6 c ?	15, 969. 42		7, 006. 62	60 cW	14, 268. 29	8– 22
6, 265. 07	2 c ?	15, 957. 11		7, 012. 52	2	14, 256. 28	
6, 271. 40	4 cw	15. 941. 00	23– 80	7, 024. 12	80 d	14, 232. 74	8– 21
6, 278. 77	4	15, 922. 29	19– 39	7, 027. 14	1	14, 226. 63	
6, 286. 40	3 c	15, 902. 97		6, 028. 50	4 c ?	14, 223. 87	
6, 290. 10	2 c ?	15, 893. 61	16– 28	7, 058. 23	4 c ?	14, 163. 96	
6, 303. 42	3	15, 860. 03		7, 059. 98	2 c ?	14, 160. 43	
6, 307. 71	100 d	15, 849. 24	21– 78	7, 066. 46	5	14, 147. 46	19– 36
6, 321. 89	120 d	15, 813. 69	22– 78	7, 108. 8	1 c ?	14, 063. 2	
6, 350. 75	80 d	15, 741. 83	23– 78	7, 129. 3	5 c	14, 022. 8	
6, 362. 66	1 c ?	15, 712. 36		7, 135. 30	4	14, 010. 97	
6, 362. 93	2 c ?	15, 711. 69		7, 139. 64	1	14, 002. 46	
6, 373. 45	3 c ?	15, 685. 76		7, 172. 21	5	13, 938. 87	
6, 374. 79	3 cw l	15, 682. 47		7, 198. 41	3 c	13, 888. 13	
6, 382. 93	4 c ?	15, 662. 47		7, 228. 03	4	13, 831. 22	9– 22
6, 405. 78	1 h	15, 606. 60		7, 237. 29	1	13, 813. 53	
6, 406. 16	3 h c. ?	15, 605. 67	19–38?	7, 246. 65	100 d	13, 795. 68	9– 21
6, 411. 47	5	15, 592. 75		7, 263. 87	2	13, 762. 98	
6, 449. 28	2 c ?	15, 501. 33		7, 273. 80	50 cW l	13, 744. 19	21– 67
6, 473. 44	1	15, 443. 48		7, 281. 45	1	13, 729. 75	
6, 501. 15	2	15, 377. 65		7, 292. 68	120 cW	13, 708. 60	22– 67
6, 502. 20	2	15, 375. 17		7, 307. 50	2	13, 680. 81	
6, 510. 74	1	15, 355. 00		7, 315. 89	3 c ?	13, 665. 12	
6, 511. 48	20 c ?	15, 353. 26	14– 25	7, 324. 14	2	13, 649. 68	
6, 515. 24	5	15, 344. 40		7, 329. 2	3	13, 640. 3	
6, 529. 21	2	15, 311. 57		7, 452. 01	15 c	13, 597. 98	
6, 544. 90	3	15, 274. 86		7, 360. 09	3	13, 583. 07	
6, 545. 73	2	15, 272. 92		7, 386. 37	5	13, 534. 73	
6, 554. 63	1	15, 252. 19		7, 404. 28	1	13, 501. 99	

TABLE 1.—*The arc spectrum of rhenium* (*Re* $_{I}$)—Continued

Wave length	Intensity and character	Vacuum wave number	Combination	Wave length	Intensity and character	Vacuum wave number	Combination
7,409.45	3	13,492.57	19– 34	7,888.79	1	12,672.73	
7,440.69	2	13,435.92		7,898.39	3	12,657.33	
7,447.40	2 c?	13,423.81		7,912.90	80 c	12,634.12	12– 23
7,478.69	2	13,367.65		7,938.54	2	12,593.31	
7,481.16	2	13,363.24		7,971.05	4	12,541.95	
7,488.08	3 c?	13,350.89		7,980.70	50 c	12,526.79	12– 21
7,524.46	4 c	13,286.34		8,052.0	1 h	12,415.9	
7,526.47	1	13,282.79		8,055.98	1	12,409.73	
7,536.51	1 c?	13,265.09		8,059.98	3	12,403.57	
7,545.31	1 c?	13,249.62		8,088.16	2	12,360.36	
7,548.70	5	13,243.67		8,166.51	1	12,241.77	
7,567.83	2	13,210.20		8,185.16	3 N?	12,213.88	
7,578.70	100 cw	13,191.25	10– 23	8,293.63	3	12,054.14	
7,605.77	2 ?	13,144.30		8,300.95	3	12,043.51	
7,611.87	20	13,133.76		8,312.93	1	12,026.14	
7,620.19	60 cw	13,119.42	10– 22	8,357.52	3	11,961.99	
7,640.91	200 cW	13,083.83	10– 21	8,361.75	2	11,955.94	
7,693.66	2	12,994.15		8,399.56	1	11,902.12	
7,705.94	3	12,973.44					
7,733.59	3	12,927.06		8,417.10	60 c	11,877.32	3– 20
				8,527.68	40 c	11,723.30	14– 23
7,743.12	1	12,911.14		8,570.74	1	11,665.40	
7,769.84	3	12,866.74		8,644.8	5 h c	11,564.5	
7,789.94	1	12,833.54					
7,794.73	1	12,825.65		8,575.5	1 h	11,523.6	15– 21
7,825.84	3	12,774.67		8,705.1	2 h	11,484.4	
				8,786.7	2	11,377.7	
7,828.11	2	12,770.96		8,797.6	2	11,363.6	
7,844.13	2	12,744.89	19– 31				
7,869.58	5 cw	12,703.67					
7,880.74	1	12,685.68					
7,882.10	3	12,683.49					

Each rhenium spectrogram had an exposure to the iron arc either juxtaposed or superposed and all wave-length measurements were made relative to the international secondary standards [12] except in the interval 2,500 to 3,370 A where the iron values of Burns corrected [13] to the international scale were used. Each plate was measured in both directions, and every line was observed on at least two different plates so that each of the final mean values presented in Table 1, represents at least 4 and frequently 6, 8, or 10 micrometric readings. The average probable error is of the order of ±0.01 A except for the red and infra-red lines in which the hyperfine structure is, in general, coarser and less regular so that somewhat larger errors may occur. Complete results are compiled in Table 1 in which the wave lengths appear in column 1, estimated relative intensity and line character in column 2, wave number in vacuo in column 3, and term combinations in the last.

After the wave-length data were compiled they were carefully examined for impurities by comparison with the raies ultimes [14] of the chemical elements and with Kayser's table of principal lines.[15] The purity of the $KReO_4$ was thus seen to be exceedingly high. One line of Li (6,707.85 A) and one of Rb (7,800.30 A) were faintly present, probably as impurities in the potassium. Fe, Cu, Na, Ca, were recognized as impurities in the silver electrodes, but these and the

[12] Trans. Int. Astron. Union, III, p. 86; 1928.
[13] K. Burns, Pub. Allegheny Observatory, 8, No. 1; 1930.
[14] W. F. Meggers, International Critical Tables, V. p. 322.
[15] H. Kayser, Tabelle der Hauptlinien, Julius Springer, Berlin.

silver lines themselves were ignored in measuring the spectrograms. Among the remaining lines, which number more than 2,000, only one line of Cr (the raie ultime 4,254.34 A) was recognized as an impurity and omitted from the final list.

The identification of the raie ultime of rhenium is of considerable practical importance because there is no doubt that such a line constitutes the most sensitive test for rhenium that can be found. The Noddacks [16] assert that the optical spectrum is sensitive to 10^{-7} while the Röntgen spectrum can not detect rhenium in concentrations of less than 2×10^{-4}. Examination of 1,600 minerals from all parts of the world has revealed [17] Re in 100 of them, but never more than 0.001 per cent or 10^{-5}. This explains why all attempts to detect Re in minerals by means of Röntgen rays failed [18] until the Noddacks conceived the plan of first enriching by chemical processes the concentration which might be expected in certain minerals. It accounts also for the entire absence of rhenium spectrum lines from tables of the characteristic spectra of other chemical elements. Comparison with the arc spectrum tables of Exner and Haschek,[19] which are the most complete with reference to faint lines, fails to disclose any coincidences with the sensitive lines of rhenium in any of the following: Mo, Mn, Nb, Ru, Pd, Pt, Rh, Os, Ir, W, Ta. This is quite different from the case of hafnium which was readily identified by recognition of its Röntgen spectrum in ordinary zirconium minerals and was later found to have been represented for many years by hundreds of lines [20] in the emission spectrum tables ascribed to zirconium. The natural concentration of hafnium in zirconium ores averages several per cent, while no ores contain more than 0.001 per cent of rhenium, so that the difference in behavior is due to great disparity in concentration and not to a great difference in optical sensitivity of the characteristic spectrum lines.

The raie ultime of Mn is 4,030.76 A and the corresponding line of Re 3,460.47 A must be expected to be the most persistent one. Recent experiments in which the partial spectra of Re were photographed when Re metal powder was progressively diluted with powdered Mn confirm the supersensitiveness of this ultra-violet Re line; it reveals the presence of Re in Mn when the number of Re atoms is only 1 per 1,000,000 (10^{-6}), and according to Noddack it indicates the presence of Re in minerals even when the concentration is as low as 10^{-7}. In some earlier tests of Re concentrations in Mo and other metals it was invariably found that the blue Re line (4,889.15 A) was the most intense, and this deceived the writer at first into believing that this line was the true raie ultime analogous to Mn 4,030.76 A. Later experience, however, has shown that the blue line has superior intensity only when the concentration of Re is 0.1 per cent or more; with progressive dilution the ultra-violet line (3,460.47 A) persists after 4,889.15 A has vanished.

The structures of the rhenium spectra are expected to resemble those of the corresponding manganese spectra, although large departures from the LS coupling may occur, entailing violations of the interval rules and normal intensity formulas. The only spectrum of

[16] Ida Noddack, Zeitschr. Elektrochem., 34, p. 629; 1928.
[17] I. and W. Noddack, Metallborse, 20, p. 621; 1930.
[18] Bansanquet and Keeley, Phil. Mag., 48, p. 845; 1924.
[19] Exner and Haschek, Bogen Spektren der Elemente, Deutike, Leipzig; 1911.
[20] W. F. Meggers, B. S. Jour. Research, 1 (RP 8), p. 151; 1928.

an adjacent element with which that of rhenium may be compared is the arc spectrum of tungsten which has been partially analysed by Laporte.[21] In this case a low energy ^5D term and a higher ^5P term have been identified, both are regular, but deviate widely from the interval rule. The most complete analysis and interpretation of the first spectrum of manganese is found in the work of McLennan and McLay,[22] and of Russell.[23] The normal state of the neutral Mn atom is represented by a ^6S term arising from the d^5s^2 configuration of its 7 valence electrons. Higher metastable terms appear as (d^6s) ^4D and (d^6s) ^6D, both of which are regular. The configuration d^5sp gives rise to one $^4P°$ term, two $^6P°$ terms and one $^8P°$ term, all of which are inverted except $^4P°$. In all of the above-mentioned complex terms the interval rule is adhered to qualitatively.

TABLE 2.—*Energy levels of the rhenium atom*

Level No.	Value	j	Identification	Level No.	Value	j	Identification
1	0.00	2½	a^6S	46	38, 994.65	4½	
2	11, 583.91	2½		47	39, 064.90	2½	
3	11, 754.49	4½	^6D	48	39, 196.67	5½	
4	12, 251.22	1½?		49	39, 552.34	4½	
5	13, 826.07	1½		50	39, 655.81	4½	
6	14, 216.80	3½	^6D	51	39, 670.42	2½	
7	14, 434.03	4½		52	39, 844.68	3½	
8	14, 621.37	2½		53	39, 916.29	4½	
9	15, 058.10	3½		54	40, 493.54	5½	
10	15, 770.27	2½	^6D	55	40, 808.77	1½	
11	16, 307.02	5½	^4G?	56	40, 810.05	1½	
12	16, 327.41	1½	^6D	57	40, 821.72	2½	
13	16, 619.12	4½	^4G?	58	40, 946.47	3½	
14	17, 238.21	0½	^6D	59	40, 997.54	4½	
15	17, 330.71	3½		60	41, 163.83	3½	
16	17, 695.29	2½		61	41, 312.95	2½	
17	18, 950.15	2½	$z^8P°$	62	41, 453.14	4½	
18	20, 447.76	3½	$z^8P°$	63	41, 556.95	1½	
19	21, 775.30	3½		64	41, 843.78	3½	
20	23, 631.80	4½	$z^8P°$	65	42, 139.99	4½	
21	28, 854.15	2½	$z^6P°$	66	42, 536.29	3½	
22	28, 889.64	3½	$z^6P°$	67	42, 598.33	3½	e^6S
23	28, 961.51	1½	$z^6P°$	68	43, 341.84	1½	
24	32, 443.57	0½		69	43, 407.82	3½	
25	32, 591.51	1½		70	43, 409.06	1½?	
26	33, 408.70	2½		71	43, 453.32	4½	
27	33, 410.63	0½		72	43, 569.36	2½	
28	33, 589.08	1½		73	43, 702.14	1½	
29	33, 898.08	1½?		74	43, 800.57	3½	
30	34, 445.33	1½?		75	44, 054.15	2½	
31	34, 520.21	3½		76	44, 224.54	4½	
32	34, 818.59	2½		77	44, 308.61	2½	
33	35, 129.25	1½		78	44, 703.38	2½	e^8S
34	35, 267.84	2½		79	44, 901.06	3½	
35	35, 751.23	0½		80	44, 902.50	2½	
36	35, 922.94	4½		81	45, 082.59	5½?	
37	37, 063.57	1½		82	45, 343.49	4½	
38	37, 381.30	1½, 3½		83	45, 462.76	3½	
39	37, 697.62	2½		84	45, 937.16	3½	
40	37, 765.53	3½		85	46, 112.20	2½	
41	37, 915.84	1½		86	46, 141.02	1½	
42	38, 018.92	0½		87	46, 352.94	3½	
43	38, 224.64	1½		88	46, 374.21	4½	
44	38, 520.58	3½		89	46, 509.33	2½	
45	38, 635.35	0½		90	46, 649.36	2½	

[21] O. Laporte, Naturwissenschaften, **13**, p. 627; 1925.
[22] J. C. McLennan and A. B. McLay, Trans. Roy. Soc. Can., **3**, p. 89; 1926.
[23] H. N. Russell, Astrophys. J., **66**, pp. 283; 347; 1927.

TABLE 2.—*Energy levels of the rhenium atom*—Continued

Level No.	Value	j	Identification	Level No.	Value	j	Identification
91	47, 004. 13	1½		106	50, 359. 19	3½	e^8D
92	47, 205. 66	4½		107	50, 395. 60	4½	e^8D
93	47, 668. 98	3½		108	50, 464. 54	5½	e^8D
94	47, 859. 87	5½?		109	50, 934. 03	2½	
95	47, 899. 18	2½		110	50, 973. 02	1½	
96	47, 932. 43	3½		111	50, 988. 39	3½	e^6D
97	47, 970. 73	2½		112	50, 994. 12	4½	e^6D
98	48, 184. 10	3½		113	51, 030. 79	1½	
99	48, 569. 38	0½		114	51, 035. 48	2½	
100	49, 022. 70	2½		115	53, 392. 20	3½	f^8S
101	49, 027. 85	2½?					
102	49, 274. 89	3½					
103	50, 110. 22	2½					
104	50, 332. 62	1½	e^8D				
105	50, 340. 64	2½	e^8D				

TABLE 3.—*Multiplets in the* Re_I *spectrum*

	$z^6P_{3\frac{1}{2}}$ 28, 889. 64	$z^6P_{2\frac{1}{2}}$ 28, 854. 15	$z^6P_{1\frac{1}{2}}$ 28, 961. 51
$a^6S_{2\frac{1}{2}}$ 0. 00	3, 460. 47 (1,000) 28, 889. 57	3, 464. 72 (800) 28, 854. 13	3, 451. 88 (600) 28, 961. 45
$a^6D_{4\frac{1}{2}}$ 11, 754. 49	5, 834. 31 (500) 17, 135. 25		
$a^6D_{3\frac{1}{2}}$ 14, 216. 80	6, 813. 42 (200) 14, 672. 87	6, 829. 96 (200) 14, 637. 35	
$a^6D_{2\frac{1}{2}}$ 15, 770. 27	7, 620. 20 (60) 13, 119. 41	7, 640. 92 (200) 13, 083. 81	7, 578. 70 (100) 13, 191. 25
$a^6D_{1\frac{1}{2}}$ 16, 327. 41		7, 980. 70 (50) 12, 526. 79	7, 912. 90 (80) 12, 634. 12
$a^6D_{0\frac{1}{2}}$ 17, 238. 21			8, 527. 68 (40) 11, 723. 30
$e^6S_{2\frac{1}{2}}$ 44, 703. 38	6, 321. 89 (120) 15, 813. 69	6, 307. 71 (100) 15, 849. 24	6, 350. 75 (80) 15, 741. 83
	$z^8P^\circ_{4\frac{1}{2}}$ 23, 631. 80	$z^8P^\circ_{3\frac{1}{2}}$ 20, 447. 76	$z^8P^\circ_{2\frac{1}{2}}$ 18, 950. 15
$a^6S_{2\frac{1}{2}}$ 0. 00		4, 889. 15 (2,000) 20, 447. 76	5, 275. 54 (1,000) 18, 950. 15
$e^8S_{3\frac{1}{2}}$ 42, 598. 33	5, 270. 96 (500) 18, 966. 61	4, 513. 31 (300) 22, 150. 50	23, 648. 28 (200) 23, 648. 28
$e^8D_{5\frac{1}{2}}$ 50, 464. 54	3, 725. 76 (100) 26, 832. 56		
$e^8D_{4\frac{1}{2}}$ 50, 395. 60	3, 735. 33 (50) 26, 763. 81	3, 338. 18 (60) 29, 947. 86	
$e^8D_{3\frac{1}{2}}$ 50, 359. 19	3, 740. 41 (5) 26, 727. 47	3, 342. 25 (30) 29, 911. 39	3, 182. 87 (25) 31, 409. 14
$e^8D_{2\frac{1}{2}}$ 50, 340. 64		3, 344. 33 (30) 29, 892. 79	3, 184. 75 (50) 31, 390. 59
$e^8D_{1\frac{1}{2}}$ 50, 332. 62			3, 185. 56 (40) 31, 382. 61

Now, in the first spectrum of rhenium there are five lines of outstanding intensity; these are as follows: 3,451.88 (600), 3,460.47 (1,000), 3,464.72 (800), 4,889.15 (2,000), 5,275.54 (1,000). The first three undoubtedly represent the transition, $(d^5s^2)a^6S-(d^5sp)z^6P^\circ$, and the last two represent the transition $(d^5s^2)a^6S-(d^5sp)z^8P^\circ$. With this

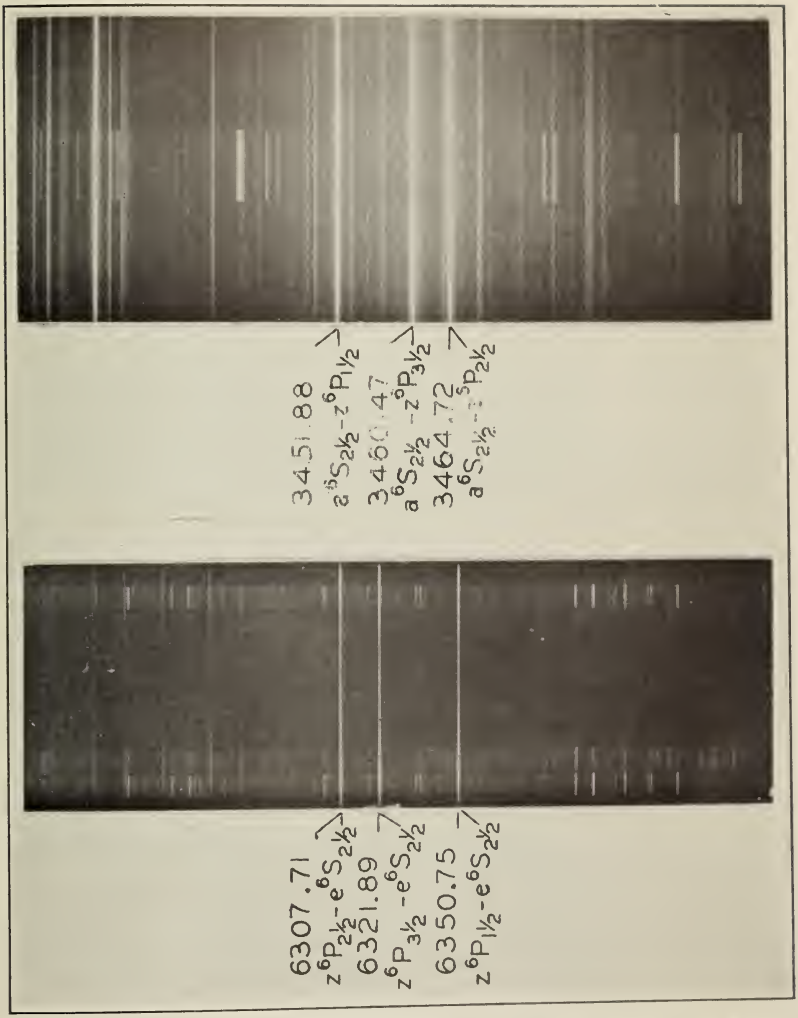

FIGURE 1.—*Two enantiomorphic triplets in the arc spectrum of rhenium, representing combinations of the threefold term, z^6P, with two successive single levels, a^6S and e^6S, the first corresponding to the normal state of the neutral atom and the second to a more highly excited state than z^6P*

The first triplet contains the raie ultime (3,460.47 A) of Re. Narrow strips of the iron arc spectrum are superposed.

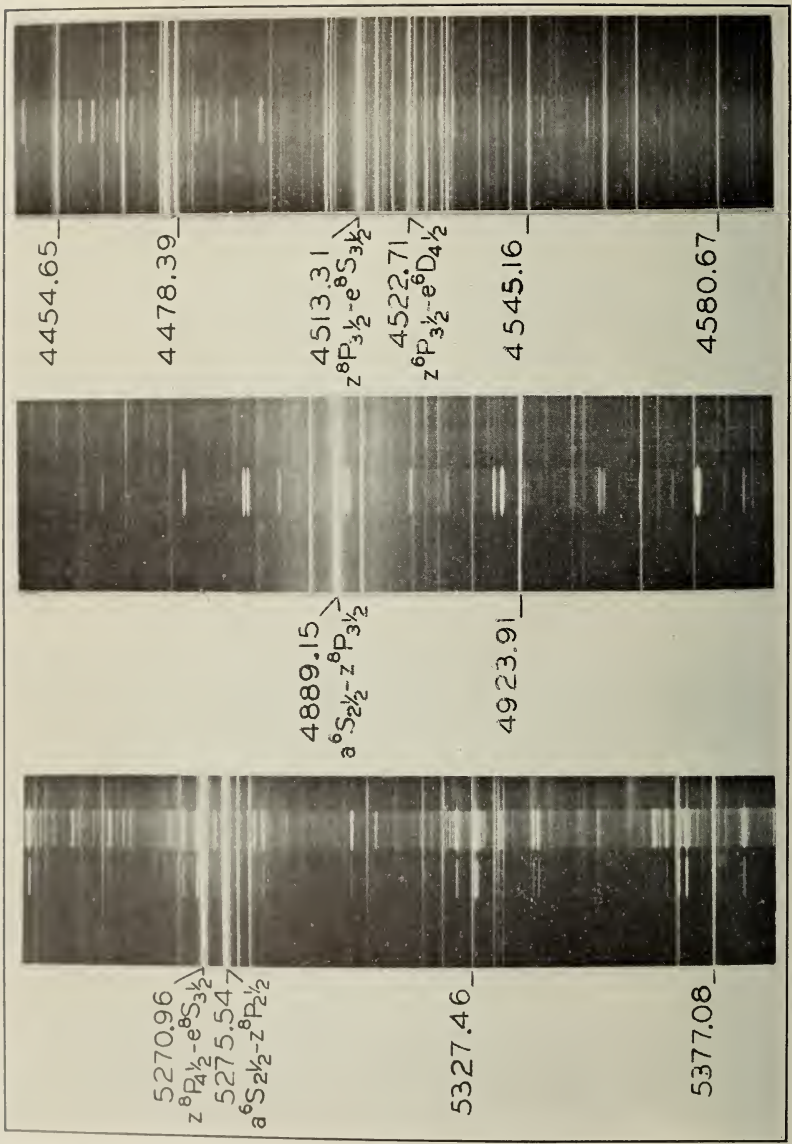

FIGURE 2.—*Portions of the visible spectrum of rhenium, including the resonance lines (4,889.15 and 5,275.54 A) and other combinations of terms belonging to sextet and octet systems*

Narrow strips of the iron arc spectrum are superposed.

clue to the structure of the spectrum and with the aid of numerous red and infra-red lines with wave number differences of the z^6P° term it was easy to establish a considerable number of levels between 11,583.8 and 21,885.3 wave number units above the ground level. The combinations of these with still higher levels account for about 500 rhenium lines, including practically all of those with intensity greater than 20, on a scale ranging from 1 to 2,000. It is to be observed that z^6P° is partially inverted and does great violence to the interval rule. Under these circumstances there does not appear to be any way at present to identify all of the remaining levels and group them with certainty into complex terms. Only the relative values and inner quantum numbers of the levels can be fixed; the combinations can be symbolized conveniently by representing the levels by serial numbers in order of increasing magnitude reckoned from zero for the ground state or level $1 = {}^6S_{2\frac{1}{2}} = 0$. The relative values of the levels thus symbolized in column 4 of Table 1 are collected in Table 2, column 2; the serial number of the term appears in the first column, the inner quantum number in the third and suggested identification of some of the levels is given in the fourth. The number of levels and, perhaps, also the identification of them can be easily extended when the spectrum has been satisfactorily observed in the interval between 2,000 and 2,500 A. A number of the principal multiplets in the Re_I spectrum are shown in Table 3, and some of the lines are reproduced in Figures 1 and 2.

In very complex spectra, such as the one under discussion, it is very difficult to find extended series of spectral terms. Only in simple spectra, where the terms are single or double levels, are long series developed (especially in absorption), but in spectra with terms of higher multiplicity it is not easy to establish the second member of a series and it is very rare that a third member is found. The combinations from successive higher series terms in these complex spectra are always faint lines and frequently of a diffuse character. Furthermore, one must be on guard against fortuitous constant differences in these complex spectra because the number of lines is large enough to find successive pairs of lines with any desired wave number separation.

As stated before, the arc spectrum of rhenium is expected to resemble that of manganese, and two series were detected in the latter by Kayser and Runge [24] as long ago as 1894. These are now interpreted as the series $z^8P^\circ - n^8S$ and $z^8P^\circ - n^8D$. From these series the absolute values of z^8P° can be calculated, and then by addition of the intersystem combinations $a^6S - z^8P^\circ$ the value of the term a^6S describing the normal state of the atom is arrived at. A similar procedure is possible with rhenium on the basis of two triplets interpreted as combinations of z^8P° with successive ${}^8S$ series terms. The wave numbers and combinations are as follows:

Wave number	Combination
18, 966. 61 (500)	$z^8P^\circ_{4\frac{1}{2}} - e^8S_{3\frac{1}{2}}$
22, 150. 50 (300)	$z^8P^\circ_{3\frac{1}{2}} - e^8S_{3\frac{1}{2}}$
23, 648. 28 (200)	$z^8P^\circ_{2\frac{1}{2}} - e^8S_{3\frac{1}{2}}$
29, 760. 38 (4)	$z^8P^\circ_{4\frac{1}{2}} - f^8S_{3\frac{1}{2}}$
32, 944. 47 (5)	$z^8P^\circ_{3\frac{1}{2}} - f^8S_{3\frac{1}{2}}$
34, 442. 99 (20)?	$z^8P^\circ_{2\frac{1}{2}} - f^8S_{3\frac{1}{2}}$

[24] H. Kayser and C. Runge, Abh. Berl. Akad.; 1894.

Unfortunately the last line appears to be masked by another. The use of a Rydberg interpolation table on these lines leads at once to the following approximate values for z^8P° levels:

$$z^8P^\circ_{4\frac{1}{2}}=39,898$$
$$z^8P^\circ_{3\frac{1}{2}}=43,082$$
$$z^8P^\circ_{2\frac{1}{2}}=44,580$$

Now this $z\ ^8P^0$ term is connected with the ground state by two inter-system combinations of outstanding intensity; they are represented as follows:

Wave number	Combination
20,447.76 (2000)	$a^6S_{2\frac{1}{2}}-z^8P^\circ_{3\frac{1}{2}}$
18,950.15 (1000)	$a^6S_{2\frac{1}{2}}-z^8P^\circ_{2\frac{1}{2}}$

and lead to the following values for the $a^6S_{2\frac{1}{2}}$ term:

$$a^6S_{2\frac{1}{2}}=z^8P^\circ_{3\frac{1}{2}}+(a^6S_{2\frac{1}{2}}-z^8P^\circ_{3\frac{1}{2}})=43,082+20,448=63,530$$
$$a^6S_{2\frac{1}{2}}=z^8P^\circ_{2\frac{1}{2}}+(a^6S_{2\frac{1}{2}}-z^8P^\circ_{2\frac{1}{2}})=44,580+18,950=63,530$$

This value of the deepest term in the Re_{I} spectrum corresponds to an ionization potential of 7.85 volts.

It is a pleasure to acknowledge the assistance of Bourdon F. Scribner with the wave-length calculations, and the advice of Prof. Henry Norris Russell as to the interpretation of the spectral terms.

WASHINGTON, April 20, 1931.

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